# INDIAN JOURNAL OF
# POWER & RIVER VALLEY DEVELOPMENT

VOL. XI NO. 7 JULY, 1961 RUPEES TWO

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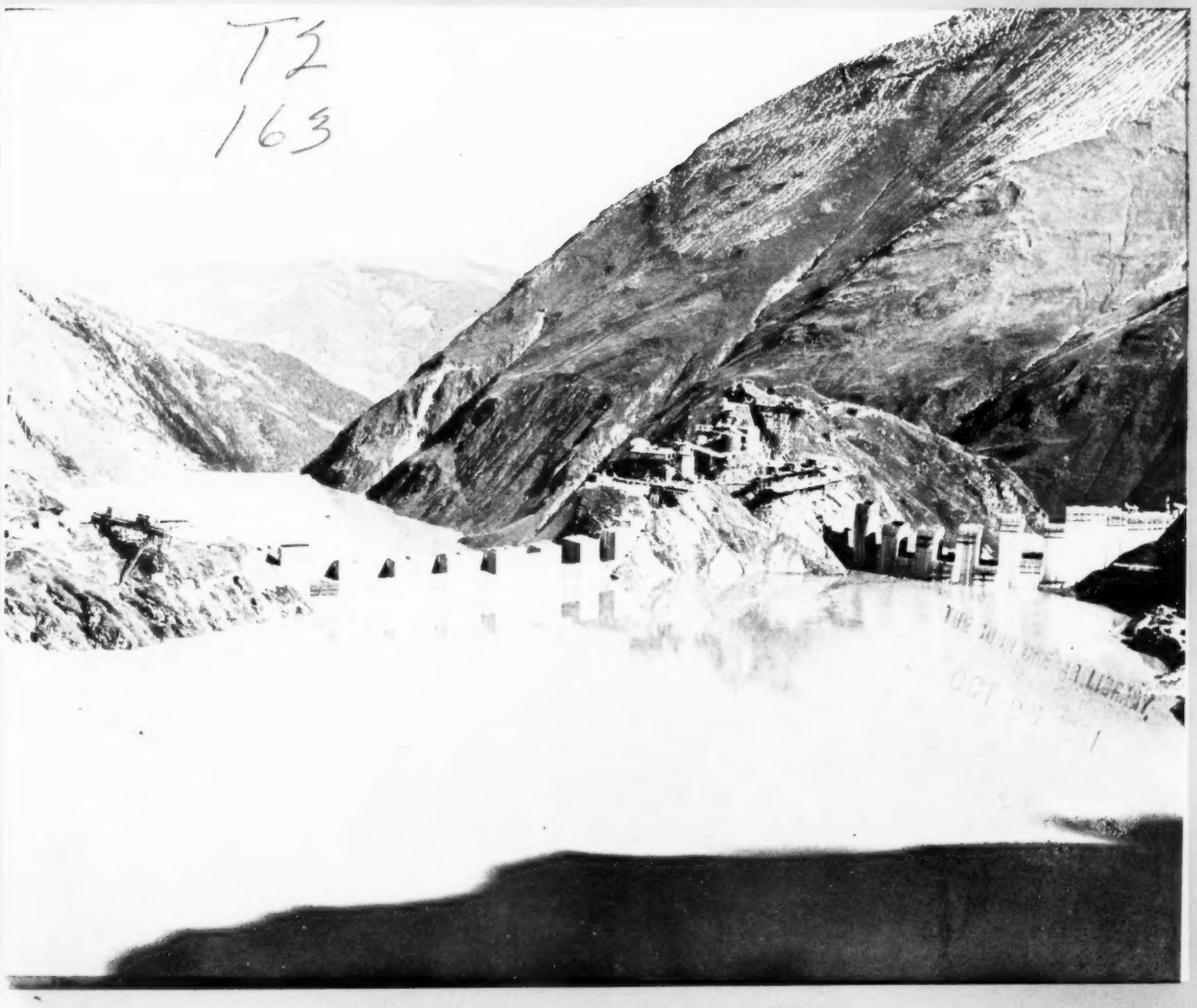

MOOSER DAM (left) and DROSSEN DAM, AUSTRIA

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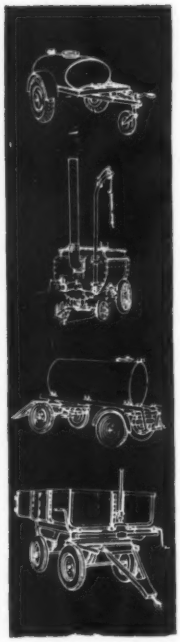

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Apply probe –
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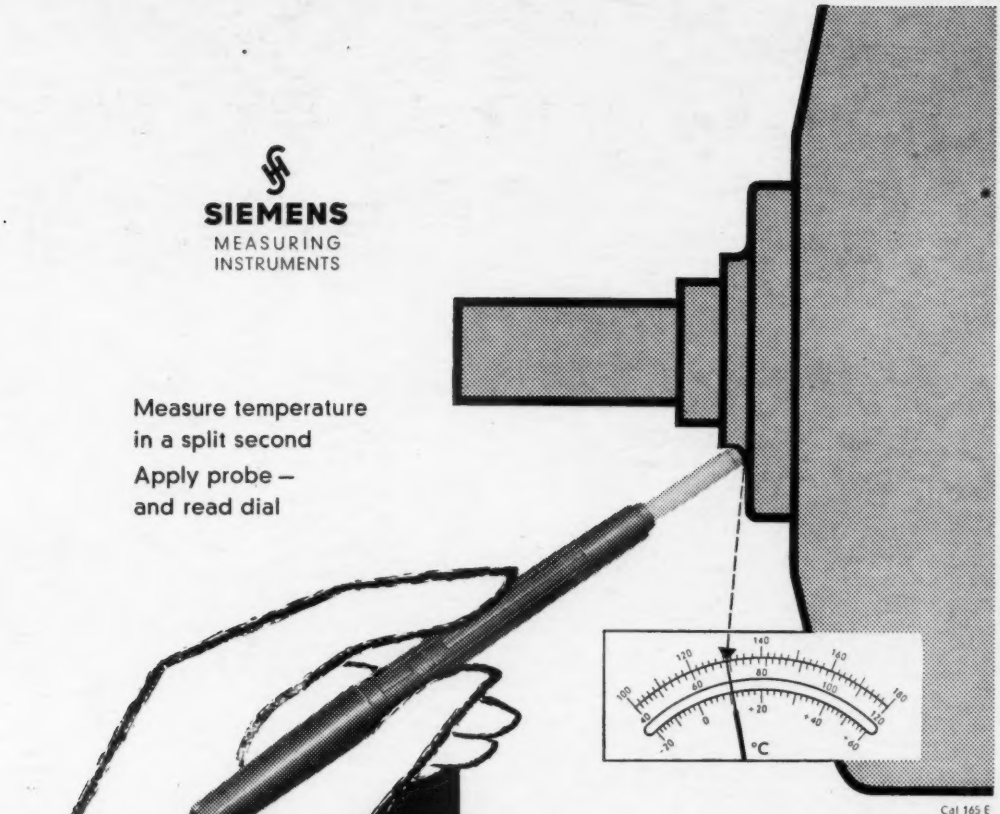


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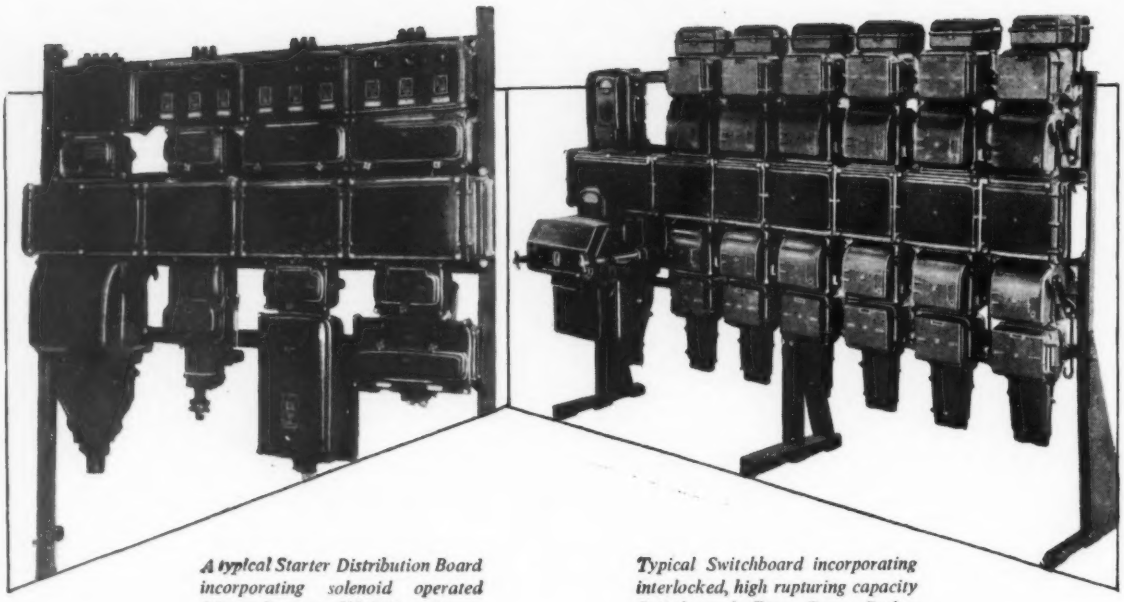
# LK Unit type, Cast iron clad, Low Tension SWITCHBOARDS...



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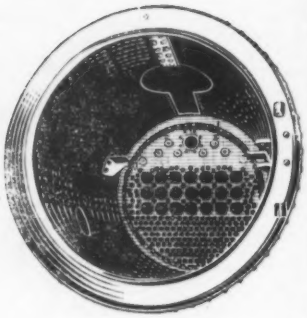

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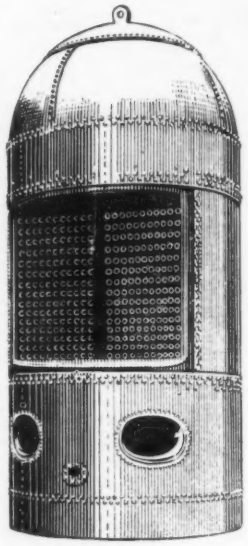

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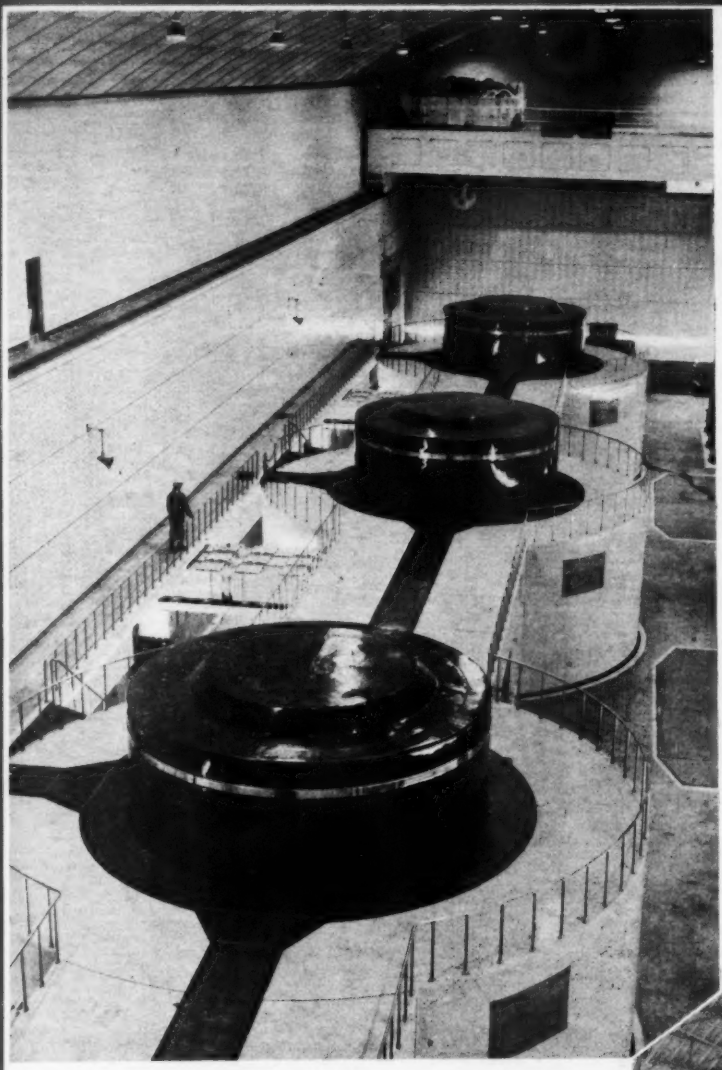

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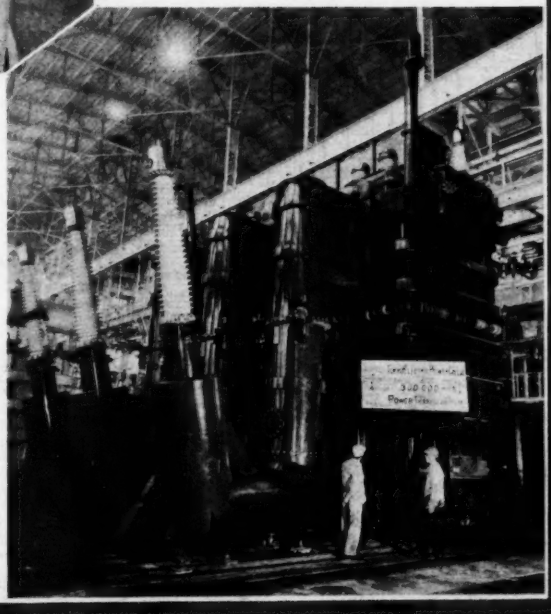

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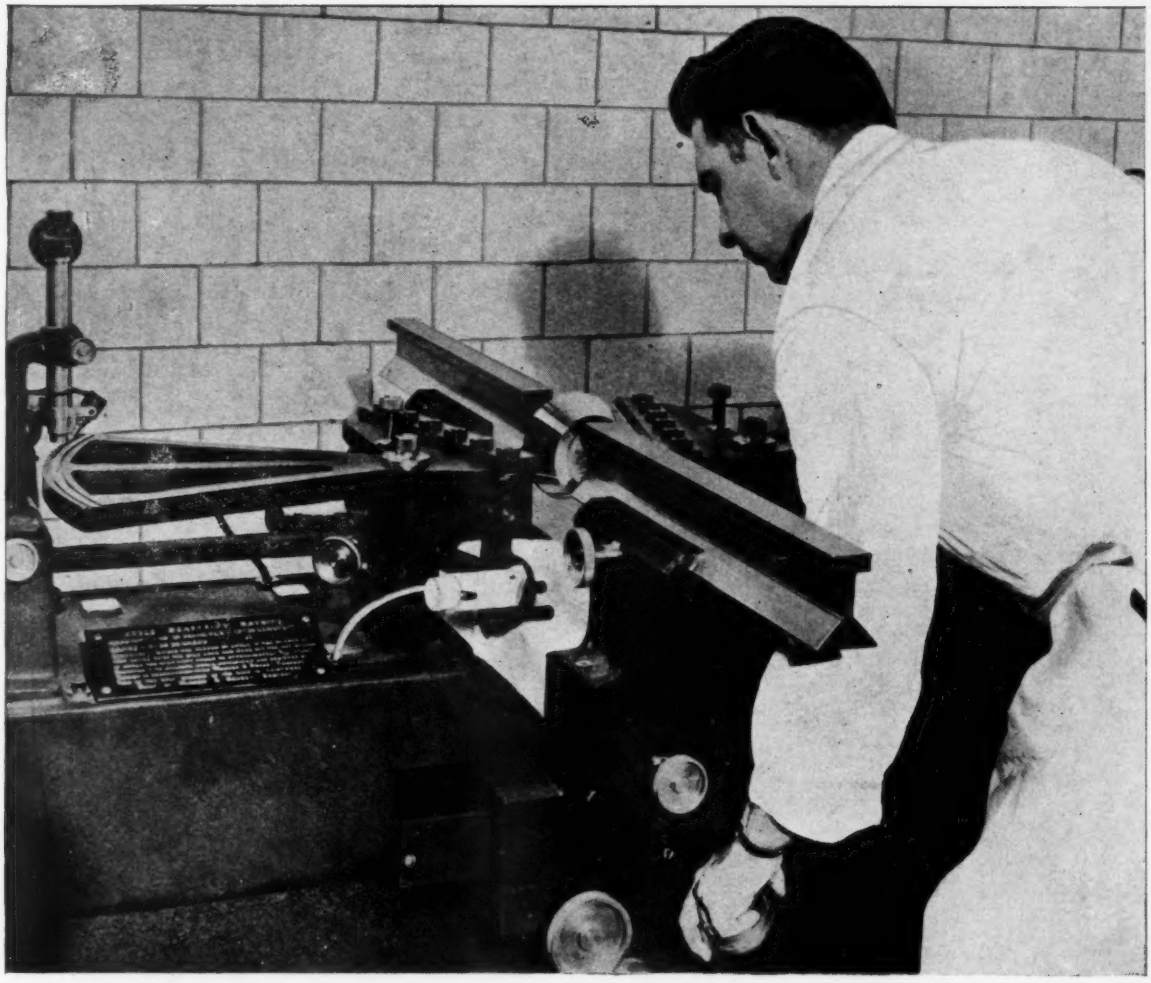

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# GANDAK & SONE PROJECTS WILL CHANGE THE FACE OF BIHAR

*Sone Barrage, Dehri-on-Sone is the job site. No mismatch here as this 262 hp,—280 Dozer push-loads this 262 hp. 210 Scraper. Matched power train components pay off with increased production.*

## Gandak Project will Change Bihar

MOTIHARI, May 22. Pandit Binodanand Jha, the Chief Minister of Bihar, exhorted the people here to co-operate with the Government in the successful execution of the Rs. 52-crore Gandak project, which would benefit not only Bihar but also Nepal and Uttar Pradesh.

Pandit Jha was addressing a public meeting at the site of the Gandak barrage at Bhaisalotan, near here. He said the project would not only provide irrigation but also large-scale employment opportunities for the people. The hydel power generated by it would help in the industrialisation of the region.

Mr. Kedar Pandey, the Deputy Minister for Irrigation, said that out of 2 crores of acres of cultivable lands in Bihar, only 18 lakh acres had been provided with perennial irrigation so far. The various river valley projects and a master plan for irrigation drawn up by the State Government would provide irrigation to one crore acre of land in the next 15 years. **The Gandak project would turn the district of Champaran into the granary of Bihar,** he said.—PTI


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## Tractor Dozers

**FAST**

High horsepower to weight ratio means high speed, dozing and push-loading, fast back-up to give short work cycles. Top travel speed : 28 mph.

**POWERFUL**

High horsepower per foot of blade assures high production on any dozing, spreading, push-loading or clean-up job.

**LOW IN MAINTENANCE**

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Servicing is simple. Each major component is easy to get at and can be removed without disturbing any other.

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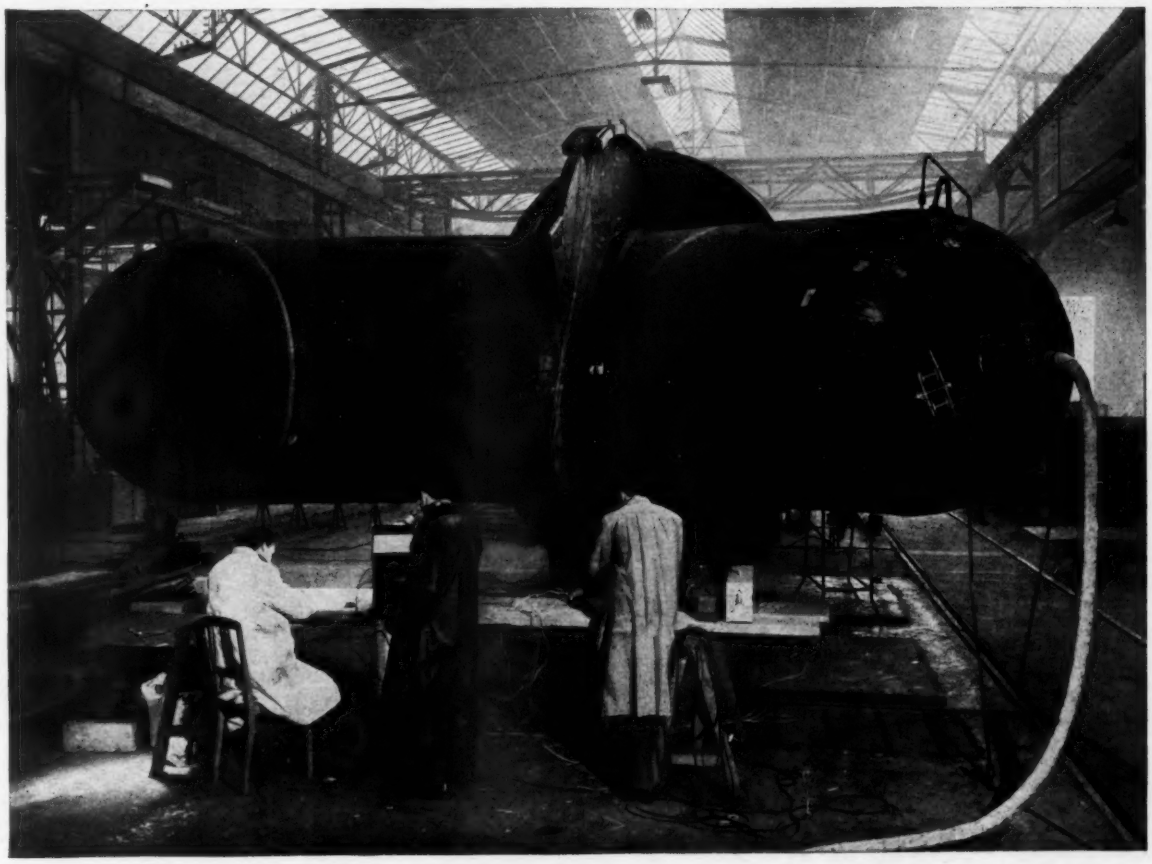

Pressure test and Electric Strain Measuring carried out on the manifold of the KOYNA POWER - STATION (Maharashtra State). Test pressure 1420 psi. Diameters 8'6"/2×6'. Thickness 1" 27/32 and 1" 37/64. Weight 40·5 tons.

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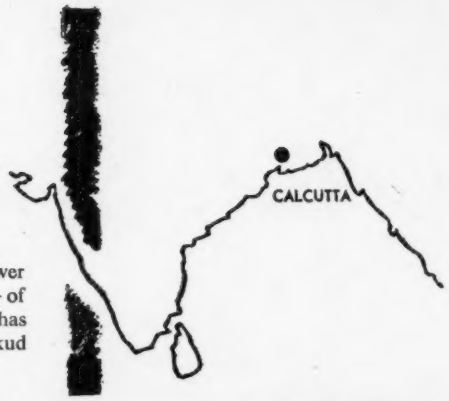
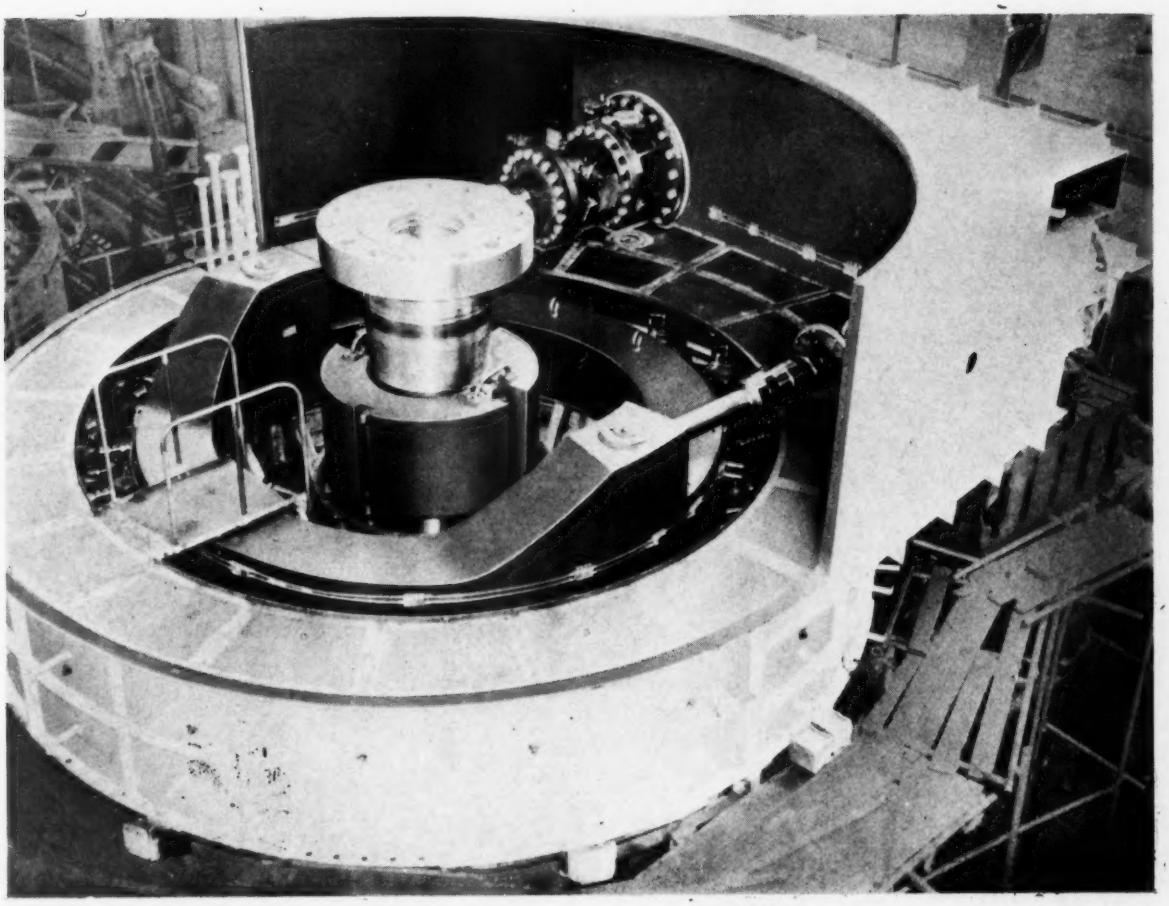
# HITACHI

## MIGHTY POWER FOR THE WATERS OF INDIA




Closely following the official opening of the Bhakra Power Station — equipped with five Francis turbines by Hitachi — of the Punjab State Government, Hitachi, Ltd. of Japan has completed a 52,000 HP Kaplan turbine for India's Hirakud No. 1 Power Station.



Transportation from Japan to India and installation of the new Hitachi turbine — the Hirakud Power Station is 300 miles west of Calcutta — is on scheduie.

Hitachi's engineers designed this giant Kaplan turbine for a maximum head of 119 feet, discharge of 5,900 cusecs and a speed of 150 rpm, and its special construction is capable of resisting massive water pressure.

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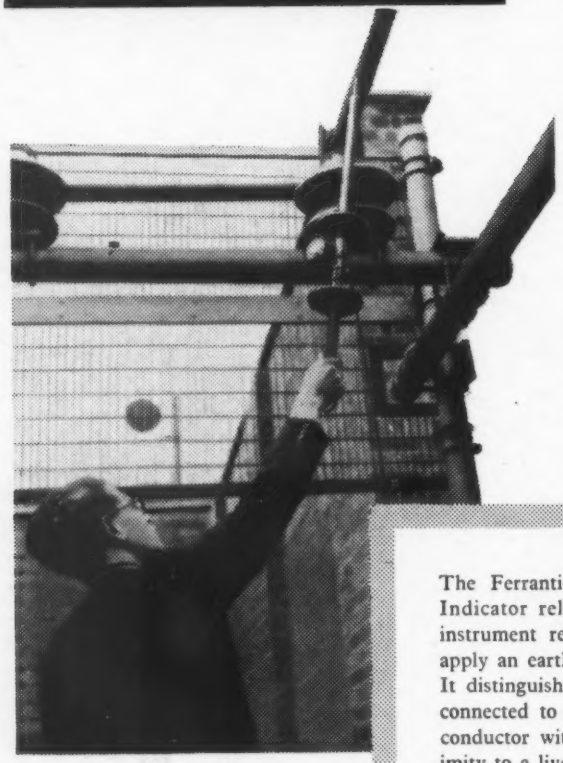
# Ferranti ELECTROSTATIC HIGH VOLTAGE INDICATORS



The Ferranti Electrostatic High Voltage Indicator reliably determines by a bold instrument reading whether it is safe to apply an earth connection to a conductor. It distinguishes between a live conductor connected to the system, an unconnected conductor with voltage induced by proximity to a live conductor, and a safe dead conductor. Two models are available, for earthed-neutral systems up to 11kV and up to 33kV respectively. The equipment is simple, robust and safe, and readily portable.

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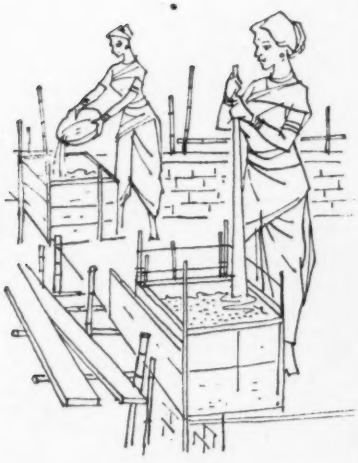

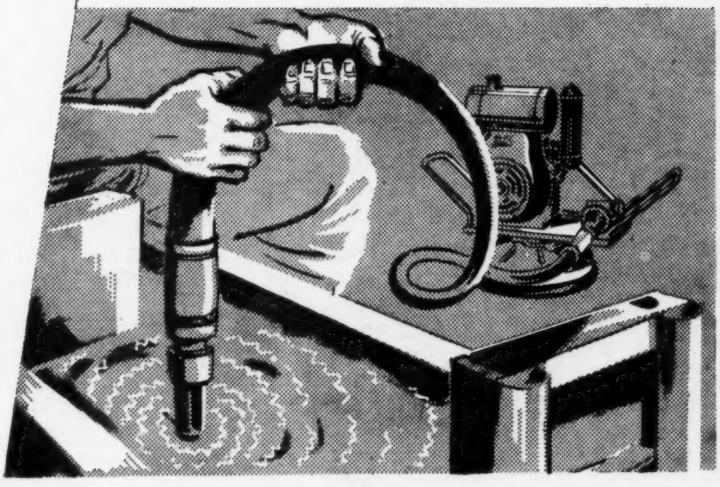

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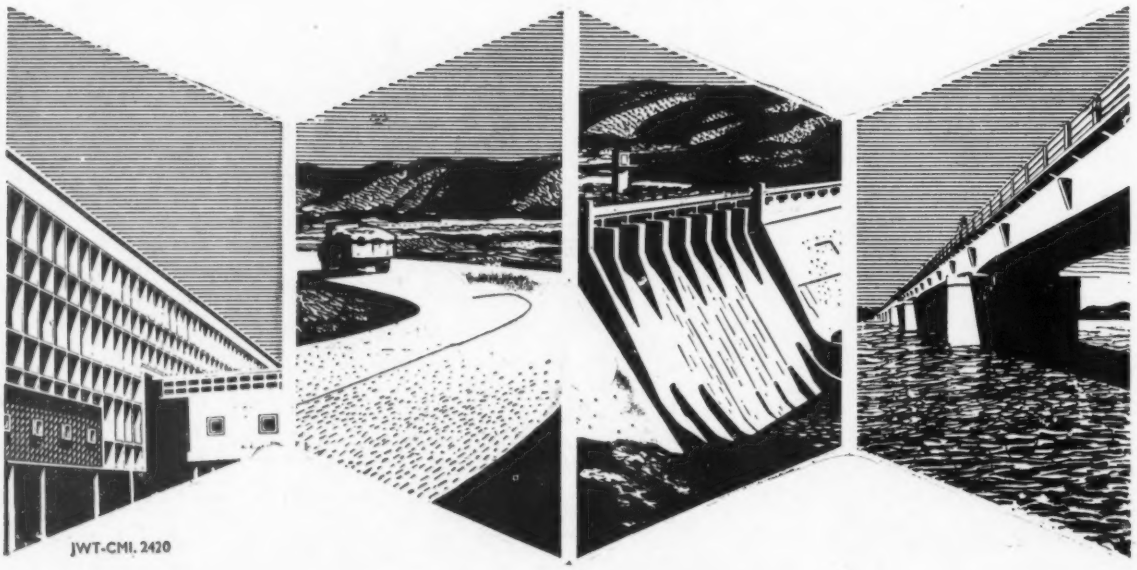

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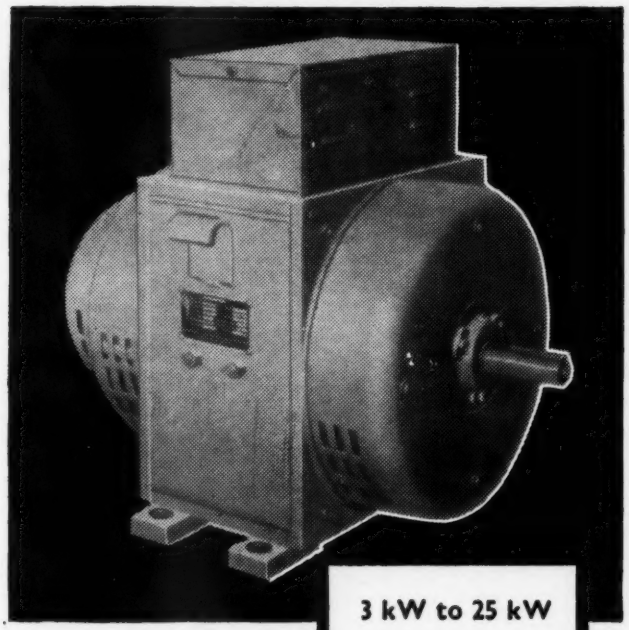
SQUARE PATH

# ALTERNATORS



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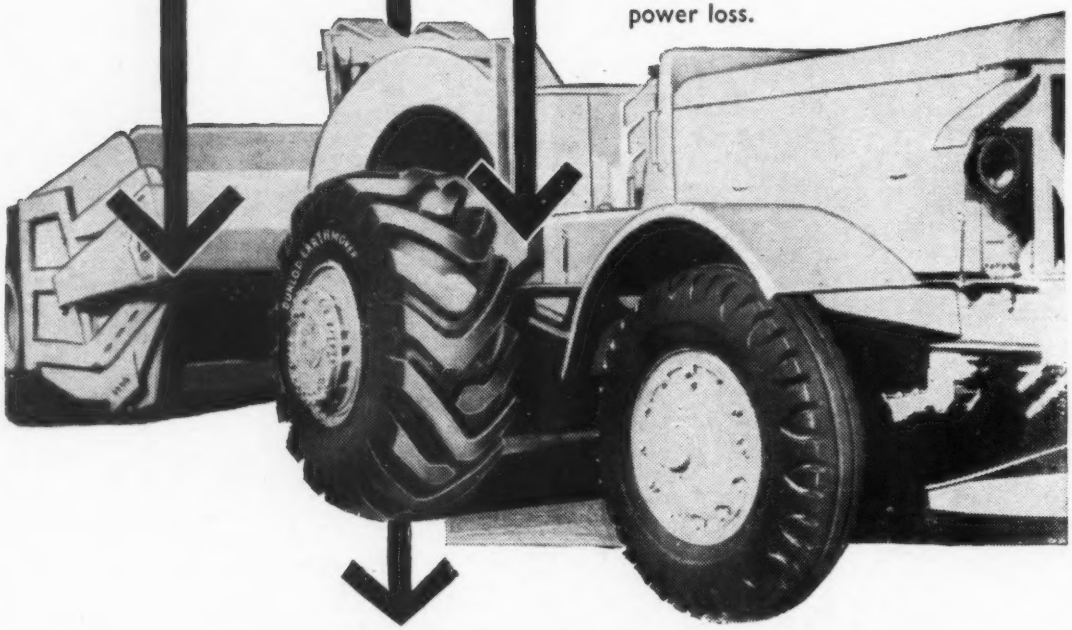


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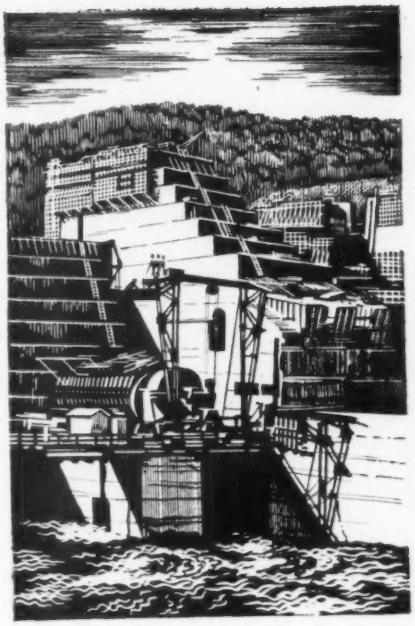

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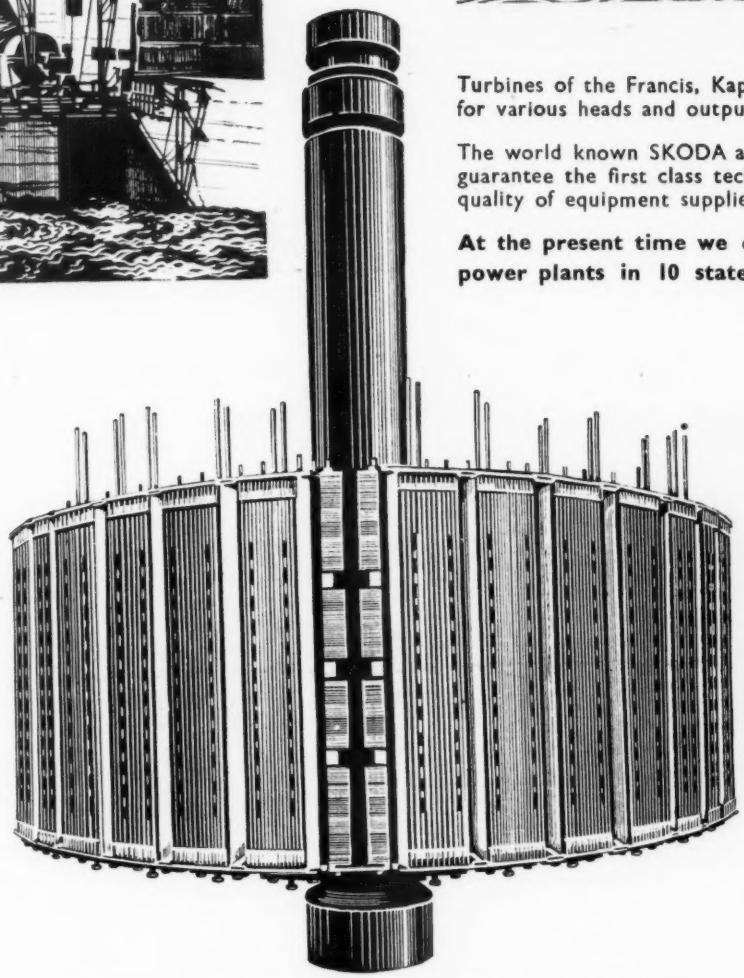

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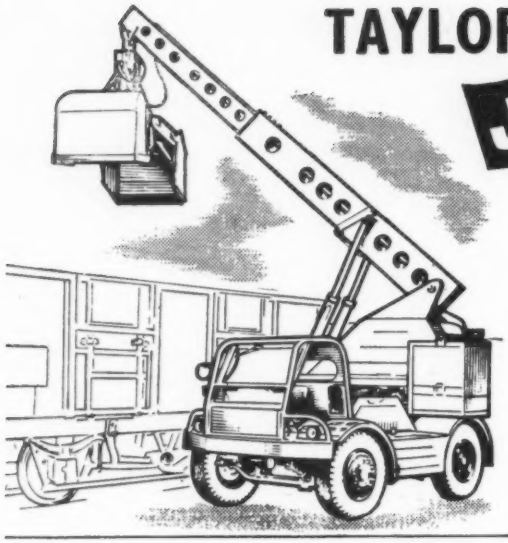

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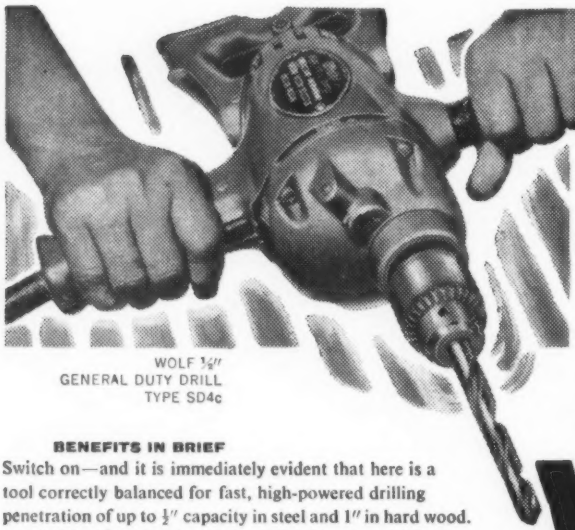

WOLF ½″
GENERAL DUTY DRILL
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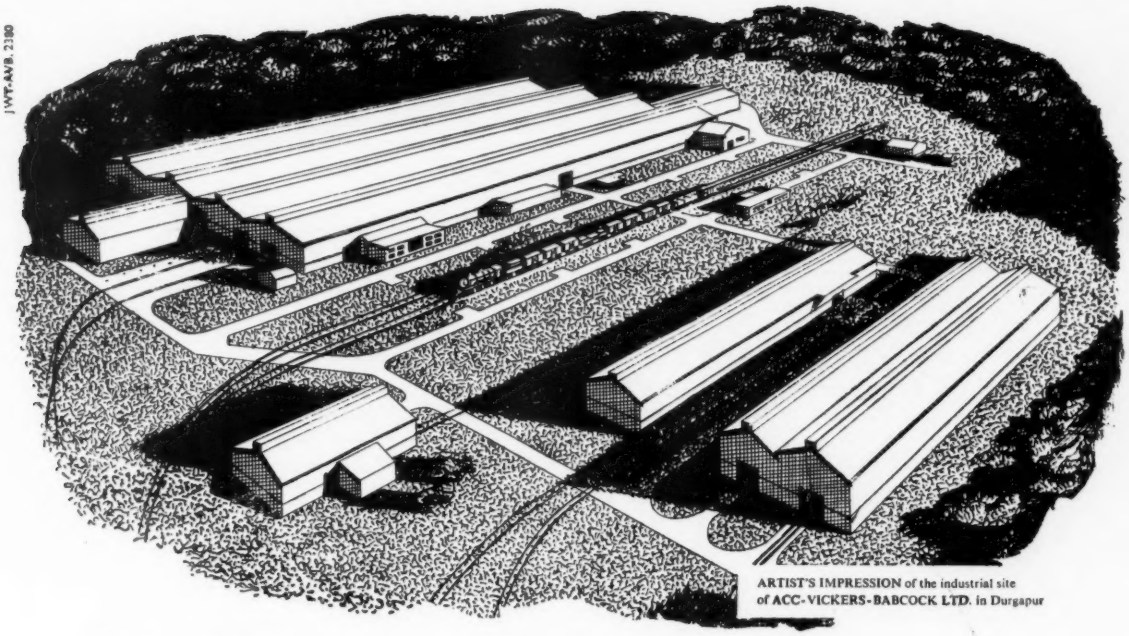

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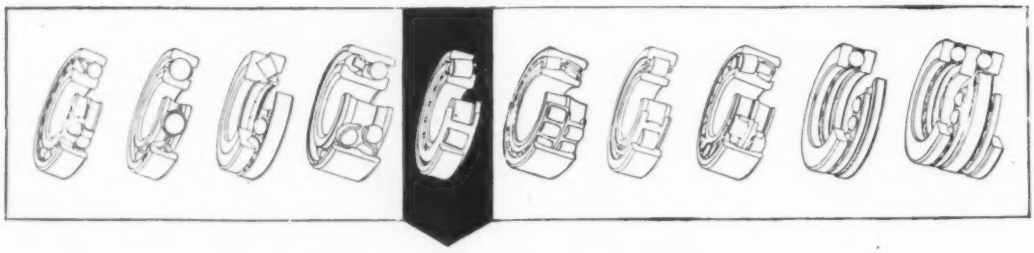

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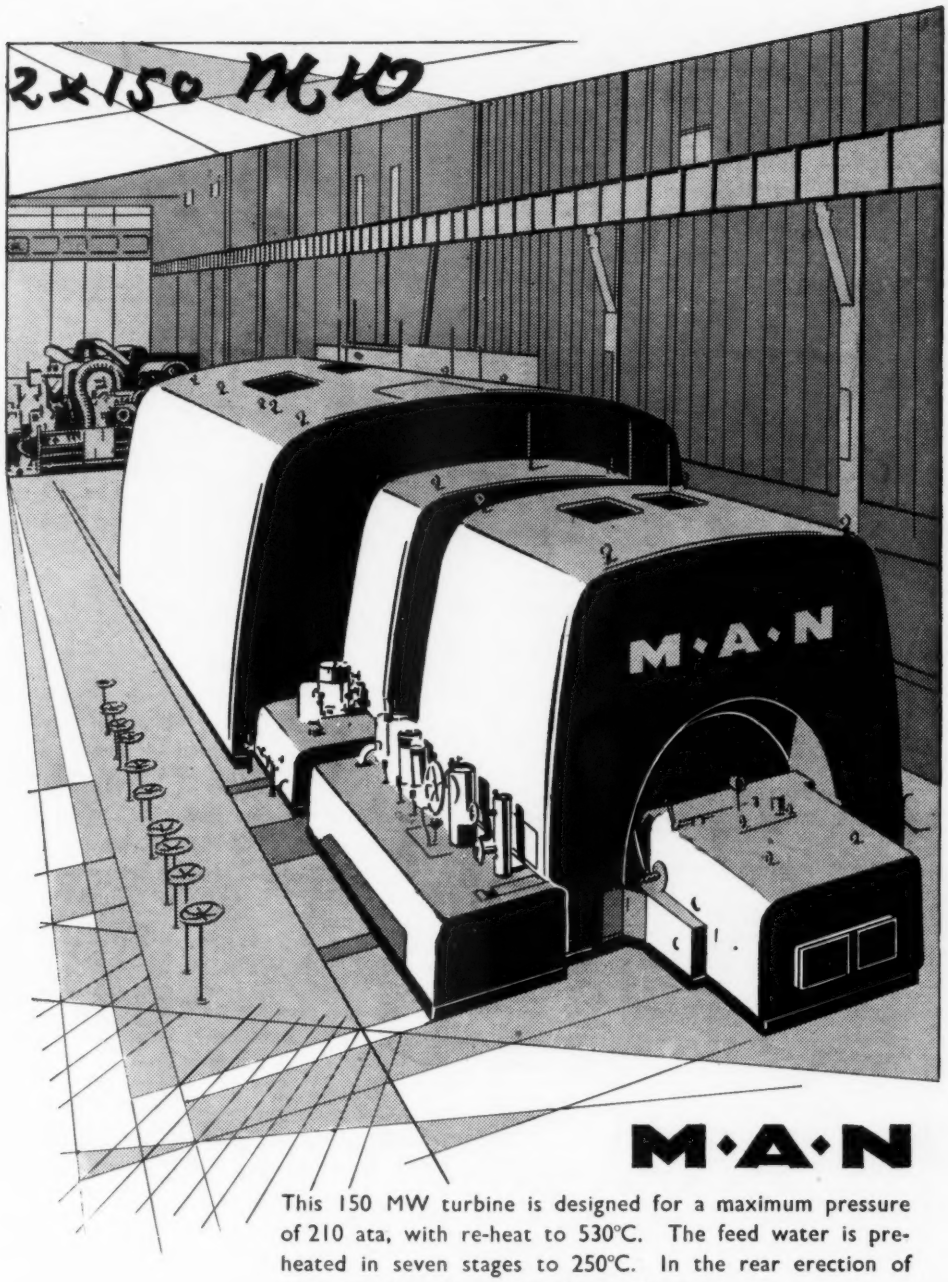


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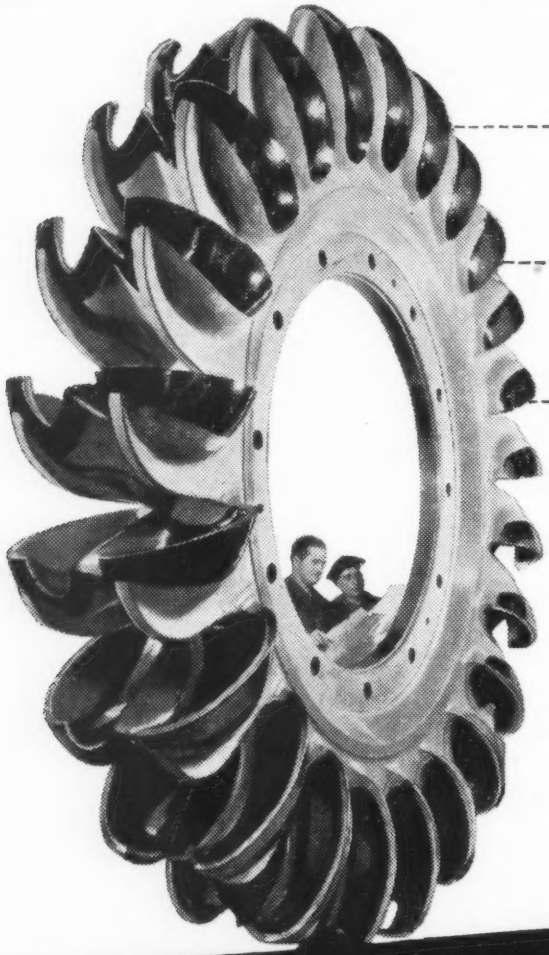

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**JULY, 1961**

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**Manoranjan Datta**
*Chief Engineer*
*West Bengal State Electricity Board*

# Electricity Supply in India and its Future

Dr. Datta was invited to deliver the Annual Lecture before the Supply Section of the Institute of Electrical Engineers, London, this year. The following is the full version of the lecture, being published in our Journal by the kind courtesy of the Institute.

In the course of his lecture, the Author after describing the characteristics of the present power situation in the country in comparison with other countries, discusses the targets and achievements, and future policy. He then deals with the pattern of consumption of power as also its generation, transmission and distribution.

We are confident that this brief survey by the author will be read with interest.—*Editor.*

## 1. INTRODUCTION

I AM deeply conscious of the honour you have done me, an engineer from nearly half way around the world, in inviting me to speak to this august company of distinguished electrical engineers. I accepted your invitation with alacrity because I felt that I could not miss this opportunity of discussing the problems and the progress of the development of electricity supply in India. I firmly believe that the subject is one of importance and that it will have far-reaching consequences not only to the people of the newly-independent Indian nation but also to the U.K. which is equally interested in a rise in the standard of living of the millions of our people.

My coming to this country once again is a happy pilgrimage. The pleasant memories of former associations here make me glad to be here at any time, and I am conscious of the traditions and ideals which are the common heritage of the British and Indian peoples.

India, one of the youngest and largest democratic republics in the world, is a secular State with a population of over 430 millions. Covering an area of 270,000 square miles, divided into 15 States with 14 official languages, it represents a colourful mosaic of races, religions and cultures.

The history of our country can be traced back to 3,000 years before the birth of Christ. Here grew and flourished the ancient Indus Valley Civilization with clear evidence of well-planned cities, wide roads, underground drainage, public and private baths and houses made of burnt bricks. Archæological evidence proves a high level of ancient civilization. Our rock-cut temples, frescoes and paintings, murals and statues, our minarets and domes, marble screens and inlaid tablets, mosques and churches, hills and valleys, lakes and rivers, our deserts and forests have, through the ages, attracted not only visitors, students and seekers of knowledge, but also invaders. India herself has never waged a war of conquest. Though the people in different regions today have their own particular languages, dresses and customs, we notice today a rich fusion of different religions and cultures in modern India.

India is richly endowed with natural gifts. In the north, we have the snow-capped Himalayas, crowned with Mount Everest. In the south lies the peninsula of Deccan, with the Arabian Sea washing its western shores and the Bay of Bengal the eastern. Between these two regions lies the great fertile Indo-Gangetic plain—the cradle of Aryan Civilization. To this day, it is the home of Indian Art and Culture. In contrast to this area, there is the great desert of Rajasthan and the dense forests of eastern and central India. In this sub-continent, Indians with various backgrounds lived and often flourished.

In India of today, we are fighting against odds to deliver the material benefits of political freedom to the largest number of our people. The outcome of that struggle will determine whether an under-developed country, with a vast population increasingly aware of higher standards of living elsewhere, can build a progressive economy, raise living standards, develop sound social institutions and achieve political stability with a democratic framework.

## 2. ELECTRICAL ENERGY IN INDIA

In spite of vast concentration around cities like Calcutta, Bombay and Delhi, the Indian economy is pre-eminently agricultural with 70 per cent of its population engaged in the production of foodgrains and cash crops.

Table I gives the distribution of towns and villages and the number of localities electrified up to 1960.

The agricultural population is widely scattered in communities of less than 250 to 5,000 people in over half a million villages. Few villages with population below 5,000 have so far been provided with electricity.

Emphasis has been placed by the Government on the industrial development during the Second and successive Five-Year Plan periods. To provide electricity at the lowest cost to the largest number of consumers, to promote small-scale industries, irrigation, pumping, etc. is a great challenge to the task of transforming a backward economy to a modern technological one.

The history of electricity supply in India dates back to the upper nineties of last century. The first thermal power station in India, constructed in 1899 in Calcutta, has steadily grown into a major system catering for the needs of Calcutta and its suburbs covering an area of 500 sq. miles, with an installed capacity of nearly 500 MW and consumers numbering about 300,000. The first hydro station (of 4500 kW) was established in 1902 in Mysore State, the generation being at 2,200 volts, 25 c/s, 3-phase and stepped up to 78,000 volts for developing the mining industry in the Kolar Gold Fields. Electricity supply was confined to remunerative metropolitan, urban and industrial areas till the middle forties of the present century. The supply was characterised by extremely small demands for power and almost imperceptible rate of growth. The aggregate plant installed capacity by 1939 was only 1700 MW with an aggregate annual output of 2,442 million kWh. The Fig. 1 summarises the progress.

The early success of the supply industry in India was due to private enterprise. Immediately after Independence, the industry was reorganised on a more rational basis better suited to the new conditions of the country. The new Government enacted the Electricity (Supply) Act, 1948 to stimulate development of all power resources of the country as national assets. Autonomous bodies were set up to form statutory Boards in the different States for the conservation, development and proper working of these sources and to operate Public Utilities. Thanks to this new structure, it has been possible to meet the ever-increasing demand and to provide for continuous extensions of the nationwide distribution net-work.

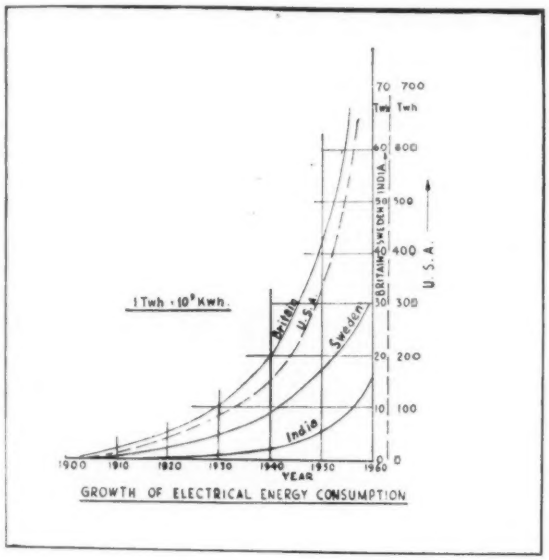



FIG. 1

TABLE I

| Population range. | No. of towns & villages. | Approx. population (estimated in million) | No. of towns & villages electrified. | Per cent of population enjoying benefits of electricity. |
|---|---|---|---|---|
| Above 100,000 .. .. | 73 | 23.784 | 73 | 100.0 |
| 50,000— 100,000 .. .. | 113 | 7.610 | 113 | 100.0 |
| 20,000— 50,000 .. .. | 401 | 11.804 | 1,041 | 84.0 |
| 10,000— 20,000 .. .. | 856 | 11.722 | | |
| 5,000— 10,000 .. .. | 3,101 | 20.824 | 20,168 | 3.4 |
| Less than 5,000 .. .. | 556,565 | 286.105 | | |

TABLE II

ENERGY CONSUMPTION AND RESOURCES

| Country | Population million | Energy Consumption: Total consumption million kWh/yr. | Electric consumption: Total million kWh/yr. | Electric consumption: kWh per head/yr. | Non-replenishable energy resources: Capital sources—Million kWh: Coal | Peat | Oil | Oilshale | Natural | Replenishable sources: Hydro: Potential in MW. | Hydro: Installed in MW. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| India | 400 | 1200,000 | 15,090 | 38 | $1800 \times 10^6$ | — | — | $170 \times 10^3$ | — | 40,000 | 800 |
| Britain | 52 | 1750,000 | 104,240 | 2005 | $290 \times 10^6$ | $13 \times 10^3$ | — | — | — | 500 | 370 |
| U. S. A. | 144 | 8800,000 | 730,591 | 4111 | $2230 \times 10^6$ | $40 \times 10^6$ | $20 \times 10^6$ | $620 \times 10^6$ | $105 \times 10^6$ | 100,000 | 18,000 |
| U. S. S. R. | 210 | 4400,000 | 231,495 | 1100 | $2900 \times 10^6$ | $230 \times 10^6$ | $272 \times 10^6$ | $2.5 \times 10^6$ | $10 \times 10^6$ | 60,000 | 1,700 |
| France | 45 | 590,000 | 58,400 | 1299 | $42.5 \times 10^6$ | $605 \times 10^6$ | $100 \times 10^3$ | $2.5 \times 10^6$ | — | 4,500 | 4,500 |
| Norway | 3.5 | 100,000 | 24,910 | 7003 | — | — | — | — | — | 7,500 | 2,900 |

Table II shows energy consumption and resources of India in comparison with some advanced countries of the world. We are still dependent on a mediæval economy, where the output of work is derived from human labour, animal power and non-commercial sources of energy such as wood, cattle-dung, charcoal, etc. In the U.S.A., the annual consumption per head is 4 MWh; in Britain it is 2 MWh; in India it is only 0.04 MWh—the average annual consumption of electricity per head of population for the whole world is 0.6 MWh. This is an indication of the leeway the country has to make up.

The load growth in different parts of our country is not uniform as it has depended upon the resources of the region and the extent to which they are developed. The energy consumption for the years 1950/51, 1955/56 and for the year 1960/61 of the five different zones into which the States have been grouped for facilitating co-ordinated zonal development, is indicated in the map of India (Fig. 2).

## 3. PLANS

The task of drawing up an overall programme of power development on a national basis under the different Five Year Plans, the first of which commenced in April, 1951 was vested in a Planning Commission. By and large, generation, transmission and distribution of electric power in India is the responsibility of the various State Electricity Boards who draw up their own programme of development. These plans are co-ordinated by Ministry of Irrigation and Power through the Central Water and Power Commission to determine overall priorities for the allocation of foreign exchange. The Commission is also responsible for co-ordinating the programme with those of other sectors of economy such as industry, mining and transport.

Two Five-Year Plans have already been completed and the third has just been started. During the two

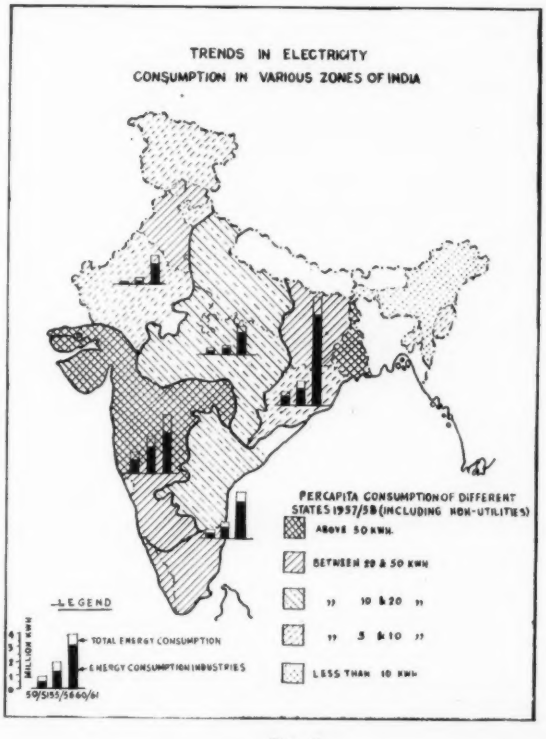



FIG. 2

Plans, generation and consumption have more than doubled as compared with an increase in agricultural production of more than 33% and industrial production of 70%.

At the beginning of the First Plan in 1951, the total installed capacity was 2,300 MW—being comprised of 600 MW in the public sector and 1,700 MW in the private sector, including industrial installations with private generating plant. The aggregate installed capacity added during the First Plan period was 1,100 MW bringing the total installed capacity to 3,400 MW at the end of the First Plan period. The aggregate plant added is no doubt meagre; but it is worth mentioning that some large water power sites developed during the First Plan, have yielded benefit during the Second and will be yielding further benefit during the Third Plan period.

The Second Five-Year Plan (1956-61) provided for a target addition of 3,500 MW in the installed generating capacity of the power plant in the country, comprising 2,900 MW in the public sector, 300 MW in the private sector and 300 MW in privately-owned industrial establishments. The target of 3,500 MW was made up of about 2,100 MW of hydro and 1,400 MW of thermal power plant. The actual achievement has fallen short of the target by 1,100 MW, but the number of towns and villages electrified has increased from 3,700 in 1950-51 to 19,000 in 1960-61.

During the present Plan, emphasis is laid on the establishment of capital industries which will make the country's economy self-sustaining and self-developing, namely, steel, heavy machine building plant, foundry forge, coal mining machinery plant, heavy structural plant, heavy plate and vessel works and heavy machine tool factories. In view of the prospect for the development of other industries which they hold out, the demand for power during the Third Plan will increase substantially. This momentum will have to be maintained if India is to achieve a self-generating economy with the choice of realising her truely immense potential.

It is proposed to increase the total installed generating capacity from 5,800 MW at the end of the Second Plan (1961) to 11,800 MW at the end of the Third Plan (1966). The programme includes nuclear power generating of 300 MW. It is expected that 15,000 additional towns and villages will be electrified during the Third Plan period, bringing the total to 34,000.

The growth of installed capacity is set out in Table III, and is graphically represented in Fig. 3.

The Hoffman Mission Report drew particular attention to the power difficulties experienced in every part of India and the impressive programme

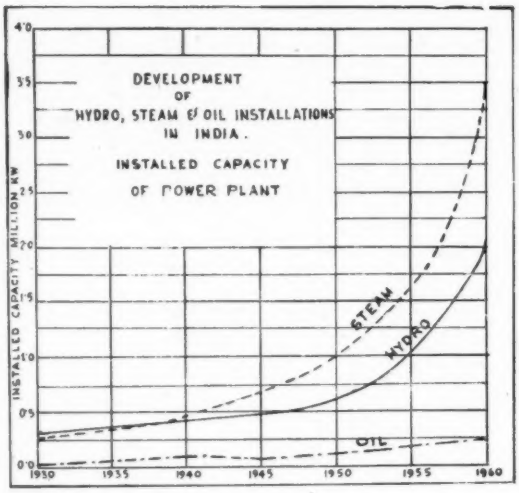



FIG. 3

TABLE III

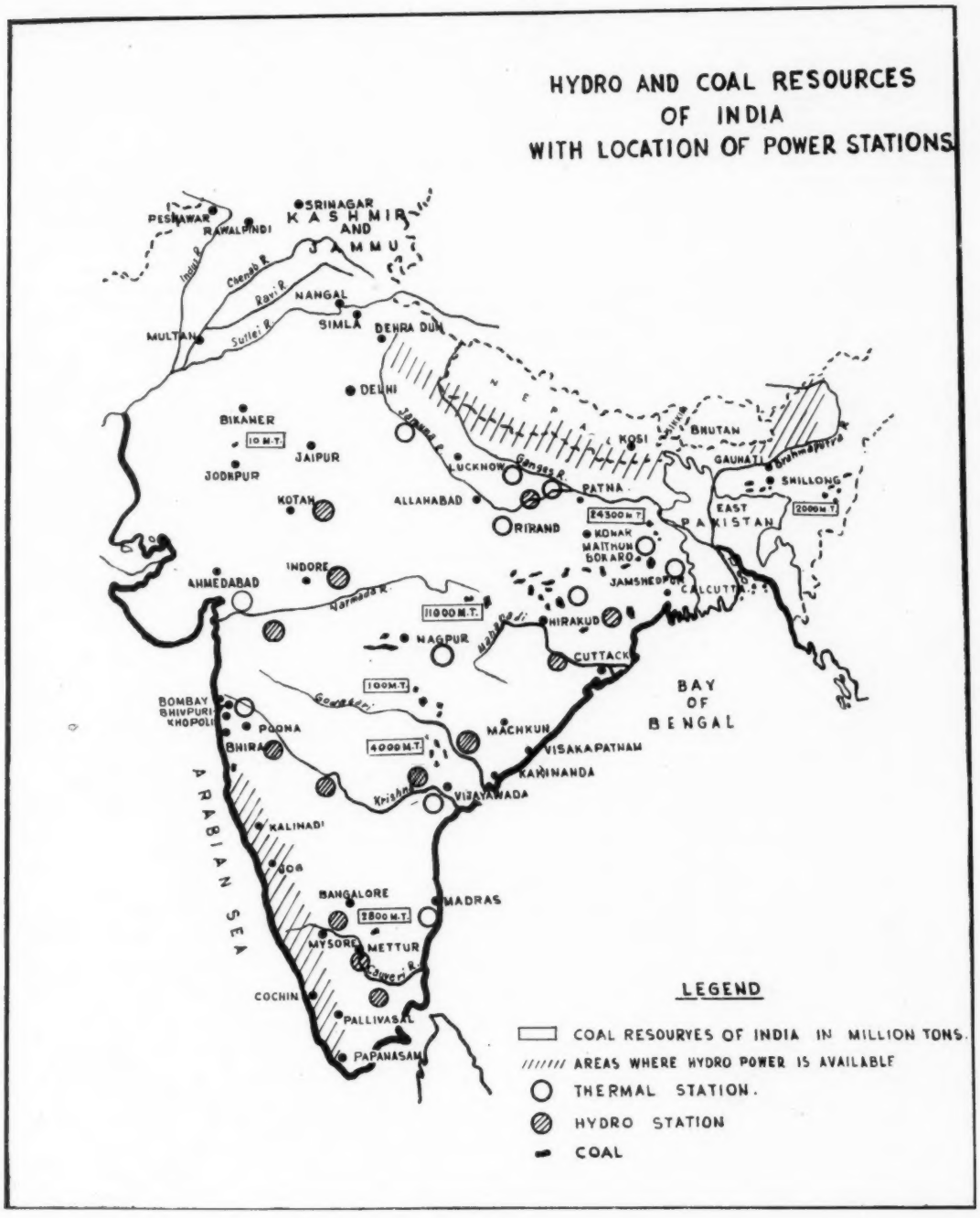
| | Millions of kW | | | |
|---|---|---|---|---|
| | 1951 | 1956 | 1961 | 1966 (estimated) |
| 1. Hydro Plant | 0.56 | 0.94 | 2.10 | 4.75 |
| 2. Steam Plant | 1.60 | 2.27 | 3.45 | 6.50 |
| 3. Oil Plant | 0.15 | 0.21 | 0.25 | 0.25 |
| 4. Nuclear Plant | — | — | — | 0.30 |
| | 2.31 | 3.42 | 5.80 | 11.80 |

drawn up for industrialisation, railway traction and rural electrification under the Third Plan. The target of 11.8 million kW of electricity output by 1965-66 may, therefore, prove to be a gross under-estimate; the demand for electrical energy by 1965-66 may be in the neighbourhood of 14 million kW.

In an under-developed economy the 'take-off', to a large extent, is determined by the quantum of power availability. Power shortage in almost all regions continues to affect the economy and there can be no two opinions about the need for power availability to be ahead of demand. An encouraging feature has been that, once power is available, demand exceeds expectations.

## 4. WHERE THE ENERGY COMES FROM

Sources of energy are plentiful, both non-replenishable (capital) and replenishable (current). Table II shows India's estimated energy resources in comparison with some advanced countries of the world. The pre-eminently current resource is hydro power.


HYDRO AND COAL RESOURCES
OF INDIA
WITH LOCATION OF POWER STATIONS
SRINAGAR
KASHMIR AND JAMMU
PESHAWAR
RAWALPINDI
MULTAN
NANGAL
SIMLA
DEHRA DUN
DELHI
BIKANER
10 M.T.
JAIPUR
JODHPUR
KOTAH
LUCKNOW
ALLAHABAD
PATNA
RIHAND
24300 M.T.
KOSI
BHUTAN
GAUHATI
SHILLONG
EAST PAKISTAN
2000 M.T.
KONAR
MAITHON
BOKARO
JAMSHEDPUR
CALCUTTA
INDORE
AHMEDABAD
11000 M.T.
HIRAKUD
NAGPUR
CUTTACK
100 M.T.
BAY OF BENGAL
BOMBAY
BHIVPURI
KHOPOLI
POONA
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4000 M.T.
MACHKUN
VISAKAPATNAM
KAMINANDA
VIJAYAWADA
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KALINADI
GOA
BANGALORE
2800 M.T.
MADRAS
MYSORE
METTUR
COCHIN
PALLIVASAL
PAPANASAM
LEGEND
COAL RESOURYES OF INDIA IN MILLION TONS.
AREAS WHERE HYDRO POWER IS AVAILABLE
THERMAL STATION.
HYDRO STATION
COAL

FIG. 4

*Hydro :* The rivers in India come under two broad categories, viz., those exclusively rain-fed, and those both rain and snow-fed. The snow-line in India ranges between 14,000 and 16,000 feet. Due to seasonal rainfall (June to September), the former groups of rivers are characterised by heavy discharge during the monsoon months, but this dwindles to mere trickle during the summer. Even in the latter group of rivers, which are of Himalayan origin, the perennial snowfeed reduces the variation of the river but slightly. Hydro power schemes in India, therefore, depend for their technical and economic feasibility on reservoirs, placed wherever there are favourable sites. A further limitation is set by irrigation, which overrides all other considerations. Taking all their limitations into account, the Central Water and Power Commission has assessed the water power potential to be 40,000 MW at 60% load factor, or about 210,000 million kWh annually, equivalent to 150 million tons of coal.

From the map (Fig. 4) it will appear that India's hydro power resources are fairly evenly distributed, with slightly more concentration in the Himalayan region.

In addition, there are resources of the same order of magnitude, located in the Himalayan foot-hill regions—Nepal, Sikkim and Tibet—which can conceivably be utilised to the mutual benefits of these countries and India. The most noteworthy is the power potential of the great U-bend of the Brahmaputra just before it enters India from Tibet. The river with a minimum unregulated flow of the order of 30,000 cusecs, drops over 8,000 ft. in a sharp 125 mile U-bend. A relatively short, 11-mile headrace tunnel would permit the utilisation of a head drop of 7,500 ft., thus constituting, without reservoir regulation, the greatest concentration of hydro power (about 130,000 million units per year) anywhere in the world.

With the technical developments in high voltage transmission it may not be uneconomical to tap these resources and transmit the power over long distances for mutual benefit of the bordering countries as well as of India.

*Coal :* The known resources of coal in India, assessed at 120,000 million tons, are localised in West Bengal, Bihar, Madhya Pradesh and Andhra. Much of the coal is of inferior quality. The economically transportable low grade coal (as distinct from metallurgical coking coal, which is both in short supply and required exclusively for steel industries) has been estimated at 40,000 million tons.

Semi-bituminous and anthracite coal best meet the requirements of power generation, although quite low grade coal can be effectively burnt. But transport of such coal to generating stations would not be easy. Pit-head power stations are eminently suitable for the loads of Bengal-Bihar coalfield areas. With the establishment of large washeries providing coking coal for steel plants, huge quantities of middlings and reject coals will be available which could be utilised for generation of power.

*Oil and Gas :* The known resources of natural gas and oil are at present limited. Results of recent exploration for oil and gas have, however, raised hopes, but it has to be expected that these would be primarily required for road, rail and air transport and to a very limited extent for generation of power mostly in isolated places.

*Nuclear Power :* Our hydro and coal reserves are concentrated in the eastern part of the country, whereas its west coast is famous for its deposits of monazite sand. India has, therefore, to install some nuclear power stations in places far remote from coal reserves and water power sites. While adequate reserve of uranium ore has been assured from Bihar and Rajasthan, India is particularly rich in its thorium reserve (500,000 tons) which is available in abundance.

India's nuclear power programme is based on thorium and this programme will, therefore, have to be developed in three stages—

(i) The first will utilise reactors fuelled by natural uranium, producing electricity and plutonium (Pu 239) as by-product.

(ii) The second will use plutonium (Pu 239) with natural uranium in fast breeder reactors or with thorium to produce uranium 233.

(iii) The third stage reactors will, however, run on thorium with Pu 239 or thorium-uranium 233 cycles. This is the stage when probably cheap and abundant power can be obtained.

The Atomic Energy Commission has initiated the first two stages, so that the country can soon get nuclear power from its abundant resources of thorium. As economic operation of nuclear power stations necessitates a high load factor, three regions, which have fairly large electrical grids and heavy industrial potentialities but are far from coalfields, have been chosen in Western, Northern and Southern India for nuclear stations.

Table IV illustrates the economics of different sources of power.

Factors affecting choice of schemes for power generation includes finances from foreign sources. The foreign exchange component of coal-fired power stations is two or three times that of hydro stations, while nuclear stations require still more. It is thus expected that hydro power backed by coal-fired power stations will continue to be predominant in India's programme for many years to come.

## 5. WHERE THE ENERGY GOES TO

Prior to Independence, rural areas were neglected altogether because of the meagre return on the

TABLE IV

CHARACTERISTICS OF GENERATING PLANT

| | Conventional | Nuclear | Gas Turbine | I. C. Engine | Hydro | Tidal | Wind | Solar |
|---|---|---|---|---|---|---|---|---|
| Capital cost—Rs./kW .. | 1000/- | 2500-4500/- | 1000/- | 1000/- | 1000-2000/- | 1500-3000/- | 1000/- | 6000/- |
| Running cost—nP per kWh | 2.5 | 2.0 | 3.0 | 6.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| Output—kWh/year/kW .. | 8000 | 8000 | 8000 | 8000 | 1000-8000 | 5000 | 3000 | 2000 |
| Availability—% .. | 80-90% | 80-90% | 80-90% | 80-90% | 10-90% | 30% | 20% | 20% |
| Usual type of load .. | Base | Base | Peak or standby | Peak or standby | Peak or Base | Fortuitous (Predictable in time) | Fortuitous | Fortuitous |
| Time to start .. | 2-3 hrs | 2-3 hrs. | 15 min. | 10 min. | 10 min. | 10 min. | 10 min. | 10 min. |
| Response to varying load | Poor | Very poor | Good | Good | Very good | Very good | Fair | Fair |
| Location .. | Influenced by fuel and cooling water | Influenced by safety consideration & cooling water | Anywhere | Anywhere | Topographical | Topographical | Topographical | Sunny climate |
| Size of Unit .. | Upto 300 MW. | Upto 100 MW. | Upto 50 MW. | Upto 10 MW. | Upto 100 MW. | Upto 100 MW. | Upto 1 MW. | Upto 1 MW. |
| Waste .. | Ash & Flue gas | Radio active products | .. | .. | .. | .. | .. | .. |

TABLE V

RELATIVE SHARE OF POWER USED FOR DIFFERENT CATEGORIES OF SERVICE.

| | Year | | | |
|---|---|---|---|---|
| | 1956 | 1957-58 | 1958-59 | 1959-60 |
| Domestic .. .. .. | 11.7 | 11.6 | 11.5 | 11.1 |
| Commercial .. .. .. | 6.8 | 6.5 | 6.3 | 6.2 |
| Agricultural (mainly irrigation) .. .. | 4.0 | 6.0 | 5.5 | 5.9 |
| Industrial (small & large) .. .. | 66.9 | 66.0 | 67.5 | 68.3 |
| Other Purposes .. .. .. | 10.6 | 9.9 | 9.2 | 8.5 |
| | 100.0 | 100.0 | 100.0 | 100.0 |

investment. With the initiations of Five Year Plan programmes, the importance of electric power for a balanced economic development of the country has been duly recognised. The impact of economic and other forces on the pattern of power usage at the end of the First Five Year Plan in 1956 and those of the succeeding years is given in Table V.

From the point of view of energy consumption, industrial load is the most important category followed by domestic and commercial load and then irrigation. This pattern is not likely to change significantly (Fig. 5).

The consumption of electricity in certain selected industries in 1960-61 is given in the Table VI along with the indices of the usage for each.

The existing important industries are Iron and Steel, Ferro-manganese, Aluminium, Fertiliser and Heavy Chemicals, Jute, Textile, Cement, Paper, Refractories, et., besides considerable demand for lift irrigation, track electrification and tea plantations. Some of these are discussed.

*Iron and Steel :* The reserves of iron ore in India are reckoned at 10,000 million tons—amongst the richest available in the world. The Government have established three mills in the public sector at Durgapur, Bhilai and Rourkela in collaboration with British, U.S.S.R. and the German combines for production of one million tons each per annum initially and 2.5 million tons ultimately. There will be additional steel plants constructed during the succeeding Plan periods.

TABLE VI

INSTALLED CAPACITY AND ELECTRICITY CONSUMPTION IN VARIOUS INDUSTRIES ON 31-3-1960 AND CONSOLIDATED FIGURES FOR OTHER YEARS.

| Industry. | Total number of factories. | Installed generating plant capacity as on 31-3-1960 (kW) | Power purchased from public utility electricity undertakings. (Million kWh) | Used in the industry inclusive of self-generation (Million kWh) | Index of usage (1959-60) Base year 1949 |
|---|---|---|---|---|---|
| 1. Aluminium (Primary) .. | 6 | 12,834 | 336.342 | 409.884 | 418 |
| 2. Cement .. | 27 | 121,759 | 320.524 | 834.010 | 363 |
| 3. Chemicals .. | 35 | 39,744 | 204.026 | 324.469 | 601 |
| 4. Collieries .. | 148 | 63,571 | 256.027 | 401.368 | 178 |
| 5. Cotton Textiles .. | 337 | 124,032 | 1,760.675 | 2,058.718 | 182 |
| 6. Fertilisers .. | 4 | 80,560 | 53.719 | 404.459 | 1348 |
| 7. Gold .. | 1 | 4,700 | 116.273 | 116.389 | — |
| 8. Iron & Steel (Primary).. | 6 | 298,118 | 700.129 | 1,288.621 | — |
| 9. Jute .. | 86 | 25,910 | 512.721 | 572.457 | 202 |
| 10. Paper .. | 24 | 77,028 | 147.314 | 380.992 | 228 |
| 11. Sugar .. | 105 | 72,456 | 21.917 | 136.334 | 333 |
| 12. Other Industries .. | 117 | 14,657 | 459.881 | 503.602 | — |
| Total: .. | 896 | 935,369 | 4,889.548 | 7,431.300 | .. |
| ANNUAL TOTAL FOR OTHER YEARS: | | | | | |
| 1958-59 .. | 872 | 812,419 | 4,015.48 | 6,239.58 | .. |
| 1957-58 .. | 857 | 769,439 | 3,606.36 | 5,715.66 | .. |
| 1956 .. | 890 | 759,650 | 3,299.07 | 5,414.36 | .. |

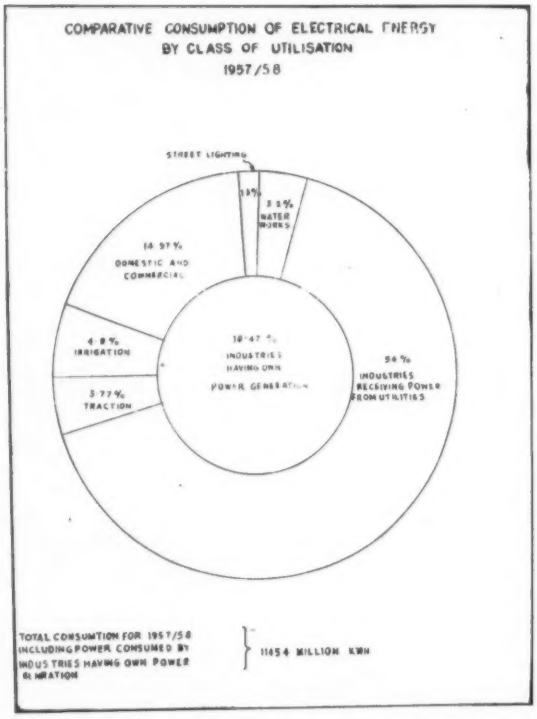



FIG. 5

*Ferro-Manganese :* India has large deposits of manganese ore, the primary raw material for ferro-manganese which is exported as such. Processing of manganese ore into ferro-manganese in addition to meeting the requirements of the country, would boost foreign exchange earnings.

*Aluminium :* Aluminium is a metal of basic importance to the economy of the country. Its consumption will increase because of the increased demand for A.C.S.R. conductors for electric power transmission and other industrial applications. Known bauxite deposits in India are estimated at 250 million tons.

*Fertilizer (Nitrogenous and Phosphatic) :* The production of nitrogeneous fertilizers will continue to increase at a rapid rate and four new fertilizer projects have been proposed during the Third Plan.

*Cement :* Cement is a basic material for construction. The Second Five-Year Plan envisages production target of about 11 million tons per year.

*Colliery Electrification :* On account of requirement of steel and transport, major attention has been given to the development of coal production. One pre-requisite for realising the target of over 90 million tons of production per annum under Third Five-Year Plan is electrification of collieries and power to meet the expansion plan.

*Railway Electrification :* Electrification of railways

will conserve metallurgical coal by using power from pit-head low grade coal-fired power stations. Total route and track lengths of the electrified sections in the Indian Railways were about 250 and 550 miles respectively at the end of the First Plan period. Under the Second Five-Year Plan there is a programme of track electrification of 826 miles on the 25 kV a.c., single phase, 50 c/s system, giving priority to those sections which are considered necessary for dealing with the heavy steel mills traffic.

*Irrigation and Dewatering:* To increase agricultural production, water raised by tube-wells would be utilised for irrigating areas which cannot be economically irrigated by canals, or in the areas the soil is better irrigated in this fashion. Besides, there will be a sizeable power demand for lift irrigation pumps for lifting water from tanks, rivers, canals, etc., as well as for reclaiming land for cultivation and habitation.

*Tea:* Tea is one of the few major items that earn foreign exchange. The tea industrialists are eager to change over to electricity not only for processing but also for electric drying. The estimated power demand of the tea industries in the State of West Bengal alone comes to about 60,000 kW at 30% load factor. The unique feature of this industry is that the extra water during monsoons synchronises with the tea demand, for it is the rain that both brings out the tea leaves and swells the streams. Hydro projects in the north of West Bengal and the State of Kerala have a ready market for seasonal power in the tea industry.

## 6. REVIEW OF POWER GENERATION DEVELOPMENTS

### (a) Hydro-Electric Power:

Water power stations are very attractive from the national standpoint. Where economic hydro sites are available, the first choice is on them.

Such development may be roughly divided into seven well marked regions, viz., Bombay, Madras, Mysore, Uttar Pradesh, Madhya Pradesh, the Punjab and West Bengal-Bihar-Orissa (Fig. 6). Some hydro installations have no relation to irrigation or to thermal generating stations. In others, power is an adjunct of gravity irrigation and the hydro-electric installation is, or will be, a constituent of an extensive grid system including one or more thermal stations.

*BOMBAY:* The early sizeable hydro schemes implemented were three stations built by Tatas in

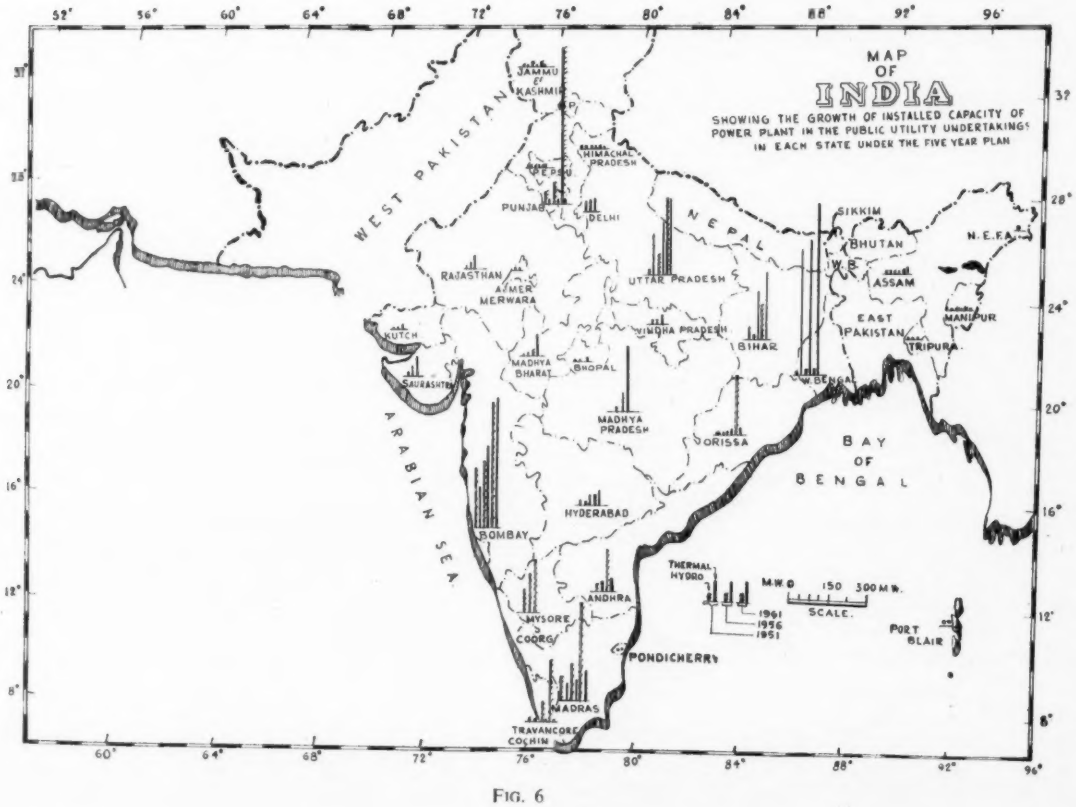



FIG. 6

the Western Ghats—the Khopoli (1915), Bhira (1925) and Bhivpuri (1927) with a total installed capacity of 235 MW—all connected to a grid system augmented by thermal power with two units of 50/62.5 MW in Trombay.

The Government has recently undertaken the Koyna Hydro-Electric-cum-Irrigation Project. This comprises the construction of a 207 ft. high dam across the river Koyna—a major tributary of the river Krishna, to impound 36,000 million ft.$^3$ of water above dead storage; water is carried through a 12,000 ft. head-race tunnel terminating on a 300 ft. high surge tank, from which pressure shafts take off to conduct water to the power house. The tail-race water will be discharged into the Arabian Sea. Initially the installation comprises four pelton wheel driven alternators each of 60 MW capacity working at a head of 1,570 ft.

*MYSORE:* The early inception of hydro electric power in India in 1902 was in the State of Mysore when the Sivasamudram Station (4,500 kW) was commissioned.

The most important project is at Jog Falls on the river Sharavathi—named after Mahatma Gandhi—with an installed capacity of 120 MW. Further extension of the Sharavathi Valley Project has recently been undertaken (Fig. 7). This project now under construction comprises of a main storage dam across the river (194 ft. high with 3.59 million acre-feet of storage capacity), the diversion of the stored water at controlled rate according to the load demand through a 6,200 cusecs capacity water conductor system consisting of 13,860 feet of open channel and 1,970 feet of tunnel bifurcating into twin pressure tunnels terminating into surge tanks from where 8 ft. dia. 4,628 ft. long penstock pipes take off to feed the individual units in the power house. The power house will ultimately accommodate 10 sets of 129,000 B..P.H. impulse turbines working under a head of 1,525 ft. Each turbine will be coupled to a 89 MW synchronous generator with a projected ultimate installation of 890 MW.

*MADRAS:* In 1924, the Government of Madras embarked on an electrification programme and developed five major hydro schemes, the Pykara (the highest head plant—3,000 ft. in the British Commonwealth), Mettur, Papanasam, Moyar and Periyar.

The Periyar scheme utilises the waters of Periyar Lake in Kerala State. It is now in operation and provides 35 MW (first stage). The second and third stages will follow rapidly, bringing the total accession of new power to 105 MW. In addition to these single and multipurpose schemes, the multi-reservoir Kundah Project (180 MW) under Phase I has now been completed.

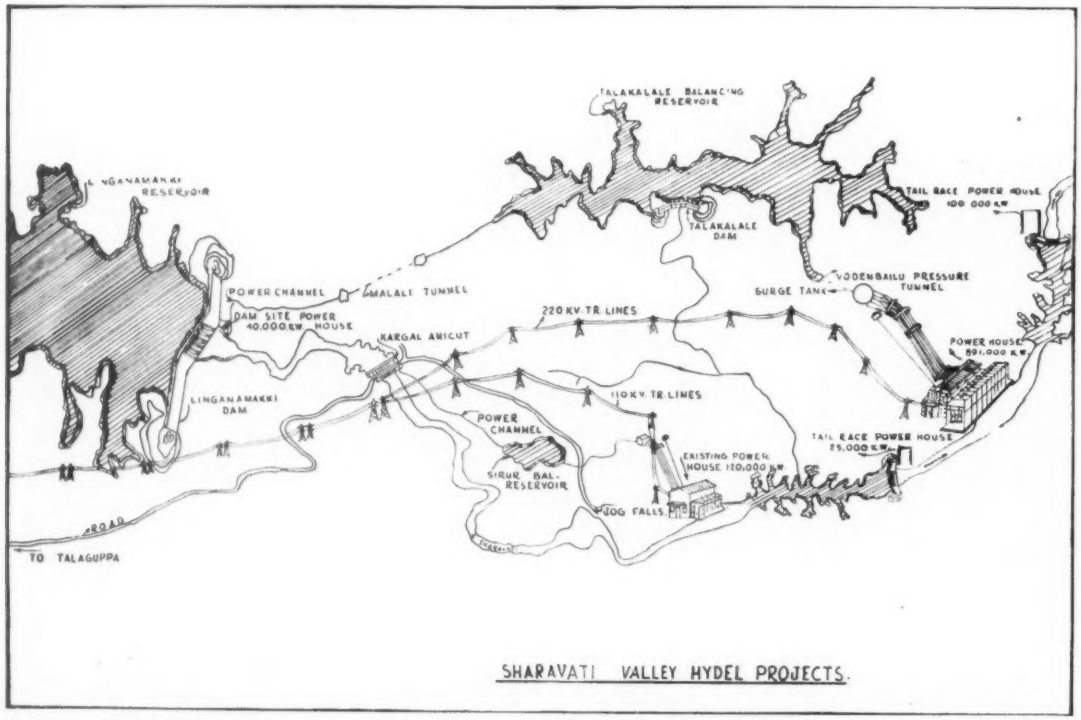



FIG. 7

The large hydro power potential in the southern portion of the Western Ghats in this region can be harnessed by mutual collaboration of these States, thus offering the possibility of the development of a regional grid, with the prospect of interconnection between Andhra, Madras, Mysore and Kerala States which is in the offing.

*PUNJAB:* The hydro development project of the State Government began in 1926 when the Joginder-nagar Station (48 MW) started operation.

The largest multi-purpose project in India, the Bhakra-Nangal Project, now nearing completion, is a joint enterprise of the States of the Punjab, *PEPSU* (Patiala and East Punjab States Union) and Rajasthan. The Bhakra dam is located across the Sutlej river in the Indus basin in a natural gorge before the river enters the plains (Fig. 8). The dam,

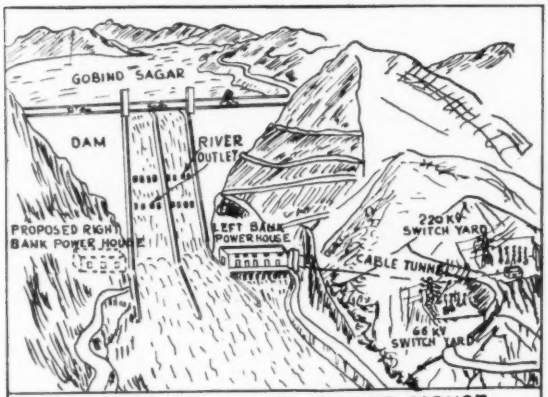



FIG. 8

now nearing completion will be 760 ft. high and will have a storage capacity of 6.8 million acre ft. The left-bank power house, already in partial operation, will have five 90 MW water wheel generators. The right bank power house will have five more units of the same rating. An irrigation-cum-power channel is taken from the Nangal barrage, five miles downstream of the main Bhakra dam. Two low head power stations each with two 24 MW units have been constructed on the channel at Gangwal and Kotla.

*UTTAR PRADESH:* In the U.P., the course of the Ganges canal, as it flows towards the south, passes over a series of 13 falls varying in height from 7 ft. to 10 ft. In 1926, the Government undertook the development of the canal as a source of electrical energy and developed eight canal power stations totalling 17,400 kW. The Sarda Canal Hydro Power Station has recently been built at Katima with an installed capacity of 48 MW.

The Rihand Dam Project, nearing completion, comprises a dam 271 feet high and 3,000 feet long located across the Rihand river near Pipri village. The power house will have six generating sets of 40 MW each. The project will further provide irrigation for 1.4 million acres of land in Uttar Pradesh and about half a million acres in Bihar.

An inter-State link between Madhya Pradesh and Uttar Pradesh interconnecting the Rihand Hydro Station with the thermal station in Madhya Pradesh may materialise in the near future.

*MADHYA PRADESH:* The Madhya Pradesh will largely have to depend upon the thermal schemes. The hydro potential available at the Chambal, an inter-State river which runs partly in Madhya Pradesh and partly in Rajasthan, is being exploited. The Project envisages the economical use of the waters of the river both for power and irrigation by the construction of the following:

(a) Gandhisagar Dam and Power Station (92 MW);
(b) Rana Pratapsagar Dam and Power Station (90 MW);
(c) Kotah Dam and Power Station; and
(d) Kotah Barrage Canal System.

The first stage power development comprises of the installation of four turbo generating units of 23 MW each at the Gandhisagar Power Station and transmission of power at 132 kV in both the States of Madhya Pradesh and Rajasthan.

*WEST BENGAL-BIHAR-ORISSA:* This important region with a vast industrial potential comprises West Bengal, Bihar and the major part of Orissa above the Mahanadi river. The central and southern parts of this region are rich in coal, iron, mica, copper and bauxite.

Progressive growth of thermal power installations at Calcutta (435 MW) constituted the major power development in this region till the post-war period, when the Damodar Valley Project covering the southern portion of West Bengal and Bihar and Hirakud Project in Orissa were taken up (Fig 9).

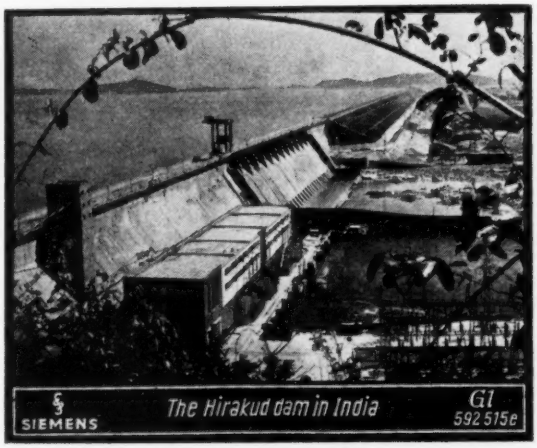



FIG. 9

At present the Damodar Valley Corporation have 479 MW of installed capacity in operation of which 375 MW accounts for the installed capacity in the thermal power stations at Bokaro and Durgapur and 104 MW is obtained from the hydro installations in Maithon, Panchet and Tilaya.

A hydro power station in the foot-hills of the Himalayas on the Jaldhaka river is now under construction. The river has its origin in the snow-bound altitudes and makes its course through Bhutan. Thereafter it constitutes the 12 miles boundary between Bhutan and Bengal. The river drains a total area of 172 sq. miles of which about 150 sq. miles fall within Bhutan. An Agreement has been reached with the Bhutan Government for utilisation of its water resources. It is proposed to harness the river in two steps to generate 54 MW at 50% load factor.

The Himalayan foot-hill region in West Bengal abounds in hydro power potential. In the future, larger resources in this sub-Himalayan region may be developed and large blocks of power may be transmitted to the southern part of West Bengal and Bihar. This will call for transmission voltages above 220 kV.

In Orissa, the multi-purpose Hirakud Project with an installed capacity of 123 MW at the main dam has already been completed. The dam has been constructed to control and regulate the Mahanadi (an east-flowing river originating in Central India) for irrigation and power. This is the longest dam in the world, 15,748 ft. long with a storage capacity of 6.6 million acre-feet. The dam site power station houses two 37.5 MW sets driven by vertical shaft Kaplan turbine and two 24 MW units. 16 miles downstream of the dam, on the tailrace channel, another power station is under construction which will have three 24 MW units. For co-ordinated development, a thermal station of 180 MW capacity has been accepted for location at Talcher near extensive low grade coal deposits in the central part of Orissa.

The trend in the various States has been towards interconnection of their important hydro-electric and thermal generating stations, but there has been no significant expansion of regional grids across State boundaries, except in the cases of Damodar Valley, the Bhakra-Nangal and the Chambal areas where there are inter-State developments of multi-purpose schemes.

(b) **Coal-fired Steam Generation :**

The interconnection of power stations and the formation of regional grids during the post-independence period have led naturally to the adoption of higher unit sizes. The rate of growth of unit sizes is exemplified by the system of the Damodar Valley Corporation.

Late in 1953, the Corporation placed in service three 50 MW units at its Bokaro Station; in 1960-61 three 75 MW units, one at Bokaro and two in the new Durgapur Station (Fig. 10); in 1964 two 140 MW units will be placed in service at the new Chandrapura station. The 75 MW and 140 MW units will follow the single-boiler single-turbine generator bloc concept. Increases in the initial steam pressure and temperature have kept pace with the increases in unit sizes. The steam conditions at the stop valves of the original Bokaro units are 850 psig and 900°F. These for the 75 MW units are 1,450 psig and 1,000°F. and for the 140 MW reheat units, the conditions will be 1,800 psig and 1,000°F. The

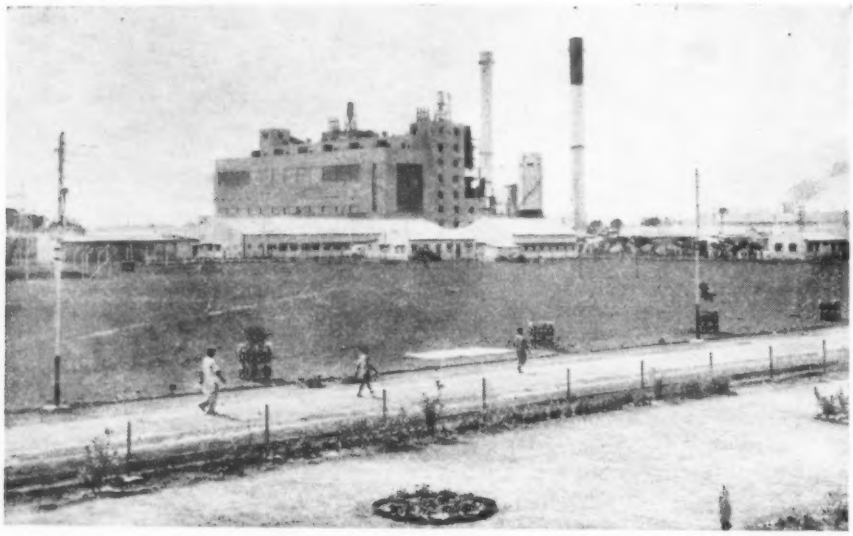


FIG. 10

Chandrapura units will be the largest in India.

All these power stations sited in the coalfields of Bengal and Bihar are designed to burn low grade run-of-mine and slack coal, washery rejects and middling coals.

Under the Third Five-Year Plan a thermal power station, now under construction near Calcutta, will have four units of 75 MW with steam condition at turbine stop valve of 1,450 psig and 1,000°F with single stage reheat to 1,000°F.

In South India, which is predominantly a hydro-electric power generating area, the Neyvelli thermal station with 5 × 50 MW sets is now under construction. This is the first run-of-mine lignite-fired power station in India, with fuel of average calorific value 5,200 BTU/lb., fixed carbon 19.1%, ash 3.3%, moisture 55.3%, volatiles 24.3%, grindability 108-127, ash fusion temperature 2,440 to 1,660°F. The turbine stop valve steam condition is 1,300 psig and 950°F.

For most of these thermal power stations commissioned within the last ten years and those now under construction, foreign credit was obtained. Naturally the norms and standards of the countries of origin are seen in the corresponding thermal stations.

The task is at present chiefly to devise ways and means for utilising inferior fuel—coking and non-coking as well as lignite with a view to conserving the more valuable resources. Stations built since 1945 generally burn inferior fuels.

Pulverised fuel firing in dry-bottom boilers is employed exclusively for all units of the Damodar Valley Corporation. This is by no means a trouble-free operation. Erosion by abrasive flyash of evaporating and secondary super heater tubes is one of the problems, while flyash disposal is just as great in India as in any other country. Cement manufacturers can take some ash for low grade cement, provided it is sharp and possesses good pozzolonic properties. However, the lack of rail and road facilities precludes, for the foreseeable future, any considerable commercial market for ash. Coals of the Damodar Valley contain ash high in refractory composition and low in halogen, properties not conducive to fluidity at low combustion temperature. Laboratory experiments suggest that lower fusion temperatures are possible if dolomite is introduced into the coal stream.

The responsibility of successfully burning the high ash coals will rest principally with the generating authorities and, in future, foreign boiler builders will be asked to share the risks of developing successful designs rather than absorbing them outright. The Central Fuel Research Institute will be encouraged to carry on research at Laboratory, pilot plant and full-scale station levels.

The new boilers for our pit-head power stations are designed to utilise pulverised fuel, coke-oven gas and heavy residual fuel as most of them are located near steel plant or coke-oven plant sites. The boiler control is designed in such a way as to enable the units to operate under automatic control with gas or pulverised coal. The heavy oil fuel burning facility is provided for stabilizing the fire at light loads and for bringing the boilers upto partial pressure after protracted shut-down.

The collection of flyash in combination mechanical-electrostatic dust collection is no longer avoidable for large boilers burning pulverised coal in dry bottoms. Gone are the days when civilised communities submit to ash baths.

All of our large new boilers must be equipped with completely automatic combustion control as it is beyond the ability of operators continuously to maintain the required vigilance. The control room is provided with schematic control panels. Boilers are provided with closed circuit television equipment. We are following modern practice of centralising the major station control elements in a single air-conditioned and pressurised space. On a single panel equipped with an integral console are contained all of the electric switches, indicators and annunciators for the remote control of the turbine and boiler. On another are contained controls of the generator and synchronising switches. Still another contains the station auxiliary electric controls.

The use of reheat for units of less than 62.5/75 MW in localities of low fuel cost is subject to special study. The capacity over 75 MW at which reheat shows an advantage depends on capacity factors, fuel cost, availability of skilled operating personnel and costs of turbine and boiler. Straight-through turbine generators of 100 MW and greater become uneconomical from points of overall length and difficulty of fitting turbine parts and condenser shells on rail wagons. The fact that reheating has not been adopted so far must be attributed to the general conservatism and absence of need for large single unit owing to inadequate interconnected system.

As our rivers in the mine fields contain so little water in the long dry season, it will be necessary to resort to cooling towers. The massive hyperbolic natural-draft tower so popular in cool and humid England is not suited to the hot, dry Indian climate. The multi-cell mechanical induced draft tower having a concrete shell and fill better meets the Indian condition.

As at present, essential development in India will still be one of interconnected hydro-electric and thermal power stations in various regions. It is conceivable that the regional systems will, in due course, be interconnected so as to form an All-India grid alongside the development of some of the larger power resources which are capable of providing ade-

quate capacities to meet the needs of supplying areas.

## 7. TRANSMISSION

The highest transmission voltage in India at present is 132 kV. A few lines now in the initial stage of operation are insulated for 230 kV. Such lines interconnect large hydro power stations or pit-head thermal power stations and a remote load centre.

*Overhead Lines*: The transmission voltages in common use in India are 132 kV, 110 kV and 66 kV and the sub-transmission voltages are 11 and 33 kV. At and above 66 kV, galvanised or black-latticed steel towers are common; 11 and 33 kV lines are borne on wood poles, rail poles and, very rarely, on reinforced concrete poles.

India is a vast country. The design conditions for transmission towers vary through a wide range from one region to another. The wind loading condition varies from 15 lb/ft.$^2$ for Central India to 30 lb/ft.$^2$ for coastal and hilly regions. It is to be noted that the worst wind load does not occur at times of minimum temperature when the conductor stress is high, but in summer, when sudden squals of short duration with a sudden drop in temperature may occur (Fig. 11). During the low temperature period, the wind load is relatively small.

Considerable economy can be effected by dividing the country into zones of wind pressure as shown in (Fig. 12). The worst load conditions for each zone must have specific reference to the regional climatic condition, the worst wind load being taken to occur at the actual temperature of each zone. Considerably increased tension in the line construction can thus be allowed so that the lines may be stressed to a much reduced sag. with consequent economics in support heights.

When the maximum wind occurs at a temperature higher than minimum temperature, the conductor length under stringing condition is:

$$L_2 = L_1 - (T_1 - T_2)\ b/aE - a\theta\ l$$

For British conditions, where maximum loading is at minimum temperature, the sign of the last term on the right-hand side is positive, and this makes a marked difference to the stringing condition.

The temperature conditions vary from 30°F to 150°F in hilly areas and 40°F to 140°F in the interior. Thermal rating of transformer and feeder equipments need to be reduced considerably in view of such high ambient temperatures (Fig 13).

Indigenous production of towers has started about ten years ago and India has attained self-sufficiency in this respect except those for river crossings where the use of high tensile steel for towers can reduce the weight by about 30% compared with mild steel.

Atmospheric lightning constitutes the most frequent cause of interruption on overhead power lines (Fig. 14). The lines and structures are generally protected by elevated earth wires over the entire length, or at least over the sub-stations and part of the adjoining lines. The chance of a direct stroke to one of the conductors is thus reduced, and the principal danger is from back flashovers. The insulation level selected is guided by the sparkover voltage of the terminal lightning arrestors. Good results have been obtained by providing an intermediate level represented by arc gaps on the insulators of the terminal plant.

The use of continuous earth wires over power conductors for sub-transmission lines at and below 33 kV is not generally favoured.

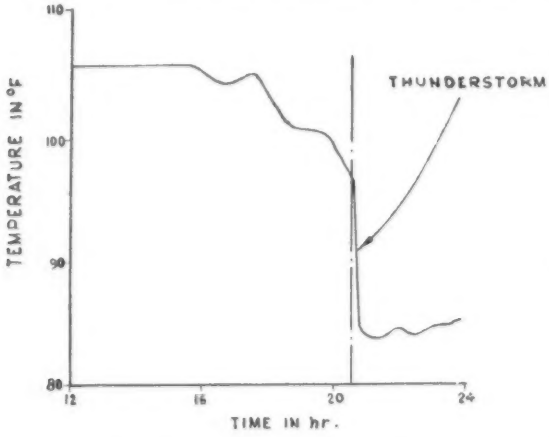
Unearthed and unbonded overhead sub-transmission lines (11/33 kV) on wood poles with wood cross arms provide not only the best performances under lightning conditions but also practically eliminate the risk of shock due to leakage current. Earlier attempts at popularising wooden supports for H.T. lines have suffered from imperfect wood preserving techniques.

*Cables:* Solid-type cable is used upto 33 kV, but at or above this voltage the cables used in India are either gas-filled or oil-filled. A 132 kV single core, gas-filled cable has recently been laid across the river Hooghly (Calcutta) through the existing 6 ft. dia. tunnel.

*Transformers:* In India transmission transformers do not normally operate on continuous full load and substantial economy can be derived in capital outlay by utilising fully the thermal capacity of transformers to meet the daily peak load.

To control distribution between parallel circuits coupled by transformers, the quadrature booster is proposed for 132 kV grids in the eastern region. There appears to be certain amount of technical shyness about the use of the quadrature boosters in our country.

*Switchgear:* In some of the 132 kV and 33 kV systems, air-blast and low-oil-volume circuit breakers are being used. Bulk-oil breakers are still




TEMPERATURE FALL AT THUNDERSTORM OBSERVATORY THERMOGRAPH RECORD

FIG. 11

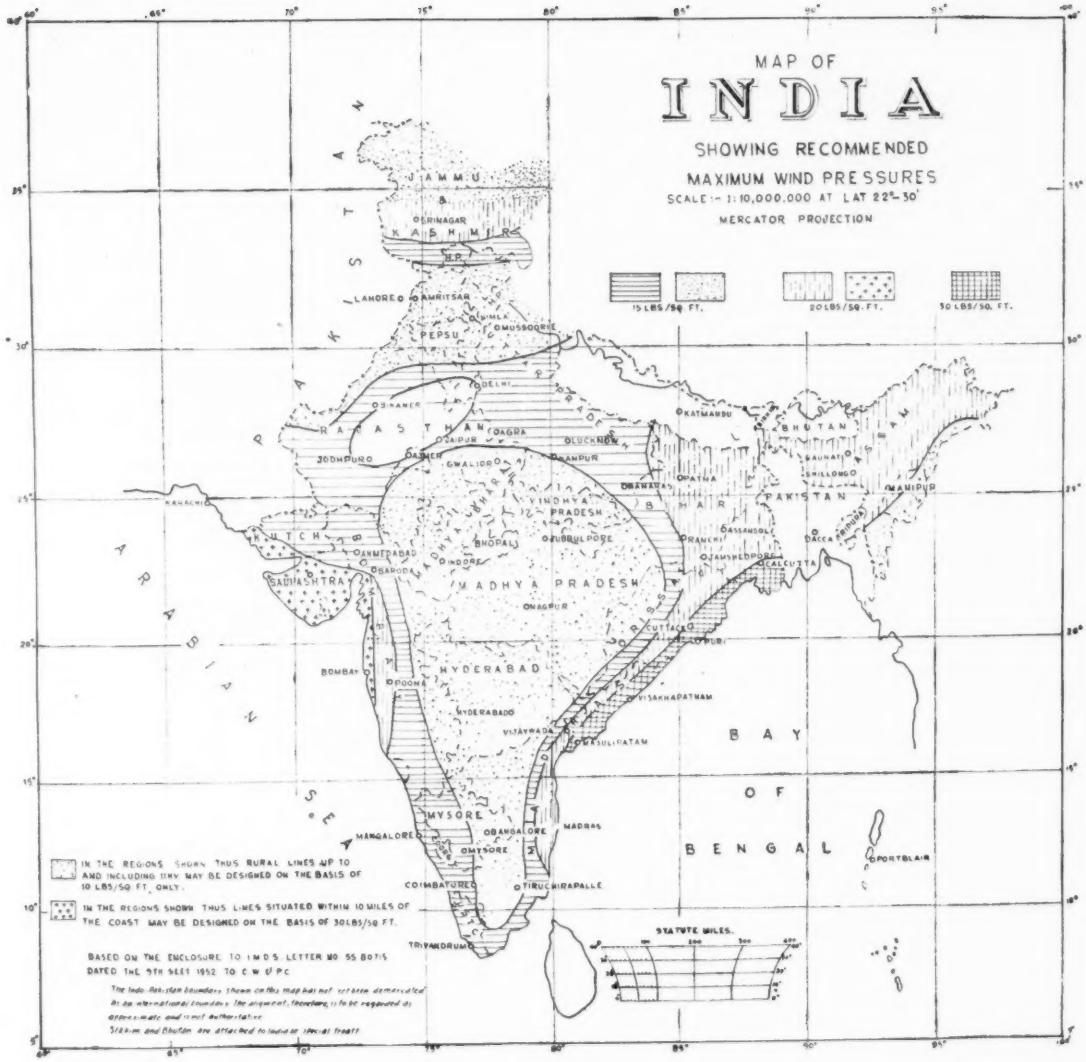



FIG. 12

in use in large numbers in the country with very good service records, but low-oil-volume breakers are becoming more popular. Most of the 66 or 132 kV circuit breakers are provided with automatic reclosing, in spite of the fact that there is always a risk of persistent faults.

*System Operation:* The design of long distance transmission system is greatly influenced by voltage drop and synchronous stability.

Reactance compensation with synchronous condensers or shunt capacitators has now been frequently adopted in our country, as the transmission of vars adversely affects the load carrying capacity. Reactance compensation with series capacitator seems to be a very useful means of improving system stability although it is still difficult to provide adequate protection against fault voltages.

To match circuit breakers having a total break time of 3 to 5 cycles, protective gear is limited to carrier current equipment using (a) either phase comparison or impedance measurement principle, (b) balanced protective devices for paralleled feeders.

Where carrier protection is not economically justified, 3 - zone distance protection with various refinements to maintain stability during phase swinging is in common use in conjunction with low-speed protective devices like induction relays for back up or directional purposes.

## 8. DISTRIBUTION

In the field of distribution, economy and efficiency are paramount. The main backbone of higher

voltage rural distribution is 11 kV, 3-phase but most spur lines therefrom (except for relatively heavy loads) are single phase. The conductors are A.C.S.R. and all aluminium, although in a very few cases where the load is small, galvanised steel conductors have also been used. There are a few experimental lines with single conductor and ground return.

Considerable economy is being exercised on the design and construction of rural distribution lines by use of indigenous material, uniformity of construction practice and the relaxation of regulations, with due regard to safety.

The major relaxations of the Indian Electricity Rules are the reduction of the factor of safety of metal and wood supports, lowering of ground clearance in built-up rural areas, omission of guards between high and low voltage lines, and restricted use of safety and protective devices such as caution boards and anti-climbing devices.

The application of wood poles goes with planned aforestation. Experiments on jointed wood poles are also being carried on. Combined use of nigh or low voltage rural electrification lines and open-wire P. and T. communication circuits is being made to minimise the capital cost of rural distribution.

In rural areas a co-ordinated use of auto-reclosers with fuses has been satisfactory. Good results have been obtained by connecting transformers solidly in groups protected by fuses or auto-reclosers.

## 9. INDUSTRY

Immediately after the Second World War, the scarcity of power plant and equipment all over the country made it clear that India's power development programme might be seriously retarded, if not completely stopped without some home manufacture of plant and equipment. Several British Organisations have been manufacturing light and medium electrical plant through their respective subsidiaries in India, or in collaboration with Indian companies.

A heavy electrical plant factory has been started at Bhopal. It is already in partial operation. When completed, it will make transformers up to 400 MVA and 220kV, circuit breakers up to 220 kV and 7,500 MVA, hydraulic turbines and generators up to 150

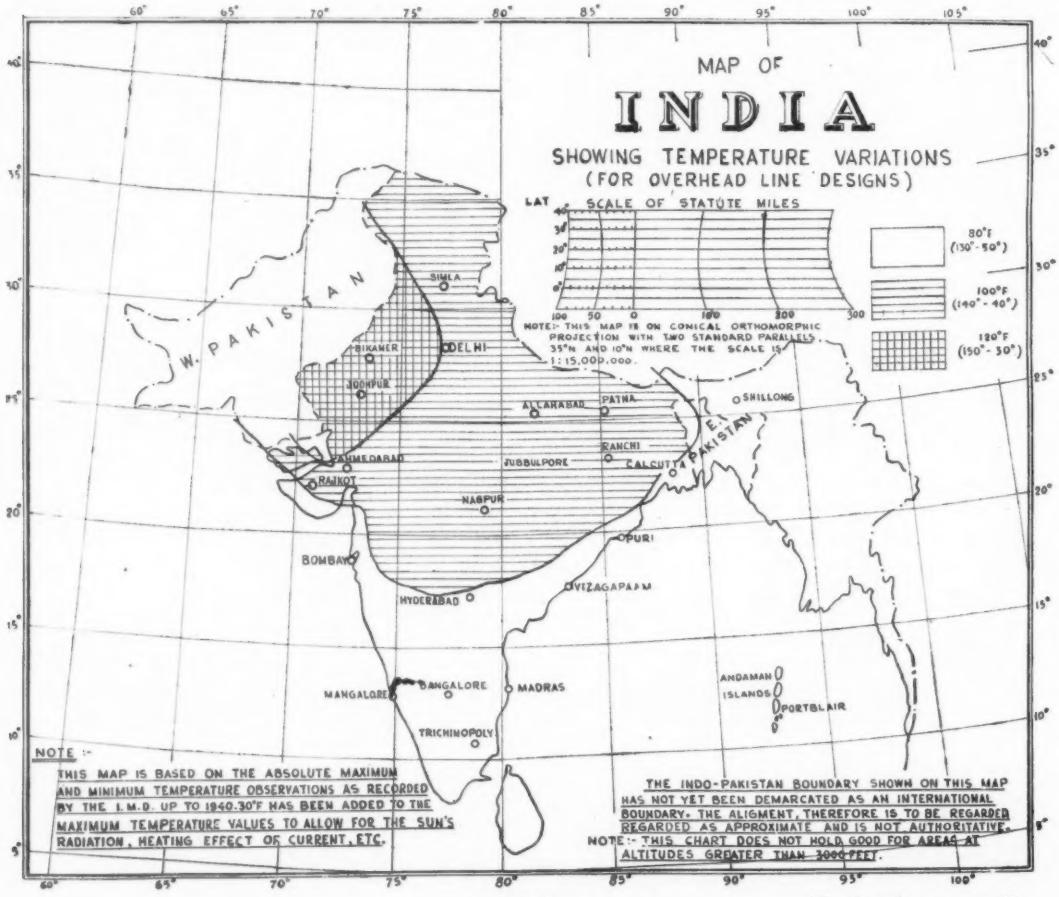

MAP OF
INDIA
SHOWING TEMPERATURE VARIATIONS
(FOR OVERHEAD LINE DESIGNS)
SCALE OF STATUTE MILES
80°F (130°-50°)
100°F (140°-40°)
120°F (150°-30°)
NOTE:- THIS MAP IS ON CONICAL ORTHOMORPHIC PROJECTION WITH TWO STANDARD PARALLELS 35°N AND 10°N WHERE THE SCALE IS 1:15,000,000.
W. PAKISTAN
E. PAKISTAN
SIMLA
DELHI
BIKANER
JODHPUR
ALLAHABAD
PATNA
SHILLONG
RANCHI
CALCUTTA
AHMEDABAD
RAJKOT
JUBBULPORE
NAGPUR
PURI
BOMBAY
HYDERABAD
VIZAGAPATAM
MANGALORE
BANGALORE
MADRAS
TRICHINOPOLY
ANDAMAN ISLANDS
PORTBLAIR
NOTE :-
THIS MAP IS BASED ON THE ABSOLUTE MAXIMUM AND MINIMUM TEMPERATURE OBSERVATIONS AS RECORDED BY THE I.M.D. UP TO 1940. 30°F HAS BEEN ADDED TO THE MAXIMUM TEMPERATURE VALUES TO ALLOW FOR THE SUN'S RADIATION, HEATING EFFECT OF CURRENT, ETC.
THE INDO-PAKISTAN BOUNDARY SHOWN ON THIS MAP HAS NOT YET BEEN DEMARCATED AS AN INTERNATIONAL BOUNDARY. THE ALIGNMENT, THEREFORE IS TO BE REGARDED REGARDED AS APPROXIMATE AND IS NOT AUTHORITATIVE.
NOTE :- THIS CHART DOES NOT HOLD GOOD FOR AREAS AT ALTITUDES GREATER THAN 3000 FEET.

FIG. 13

(Continued on page 20)

# 'ENGLISH ELECTRIC'

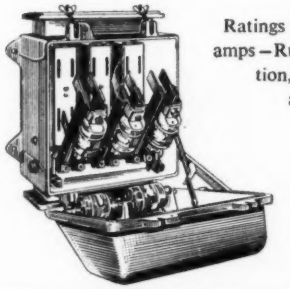
## HIGH RUPTURING CAPACITY HEAVY DUTY

## FUSEGEAR

### H. R. C. CARTRIDGE FUSE-LINKS

Hermetically sealed construction—Non-deteriorating—ASTA certified for 35 MVA rupturing capacity—Visible indication of operation—Ratings up to 300 amps.

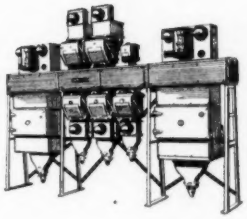
### COMBINATION FUSE-SWITCHES



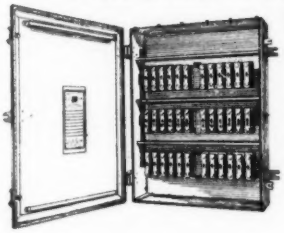
Ratings from 30 to 750 amps—Rugged construction, fully shrouded and interlocked—Type tested for 35 MVA rupturing capacity.

### COMBINATION FUSE-SWITCHBOARDS

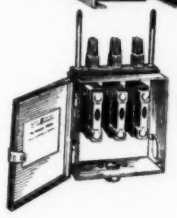
Incorporating Combination Fuse-Switches upto 750 amps—Robust and compact construction—Readily modified and extended—Type tested for 35 MVA rupturing capacity.



### DISTRIBUTION FUSE-BOARDS



Robust, dust and moisture proof construction—Type tested for 35 MVA rupturing capacity—Ratings from 15 to 100 amps.



Flexibility of power distribution—Can be installed without disturbing existing layout or production—Avoids chasing of floors for ducting—Approved by Fire Insurance Authorities.

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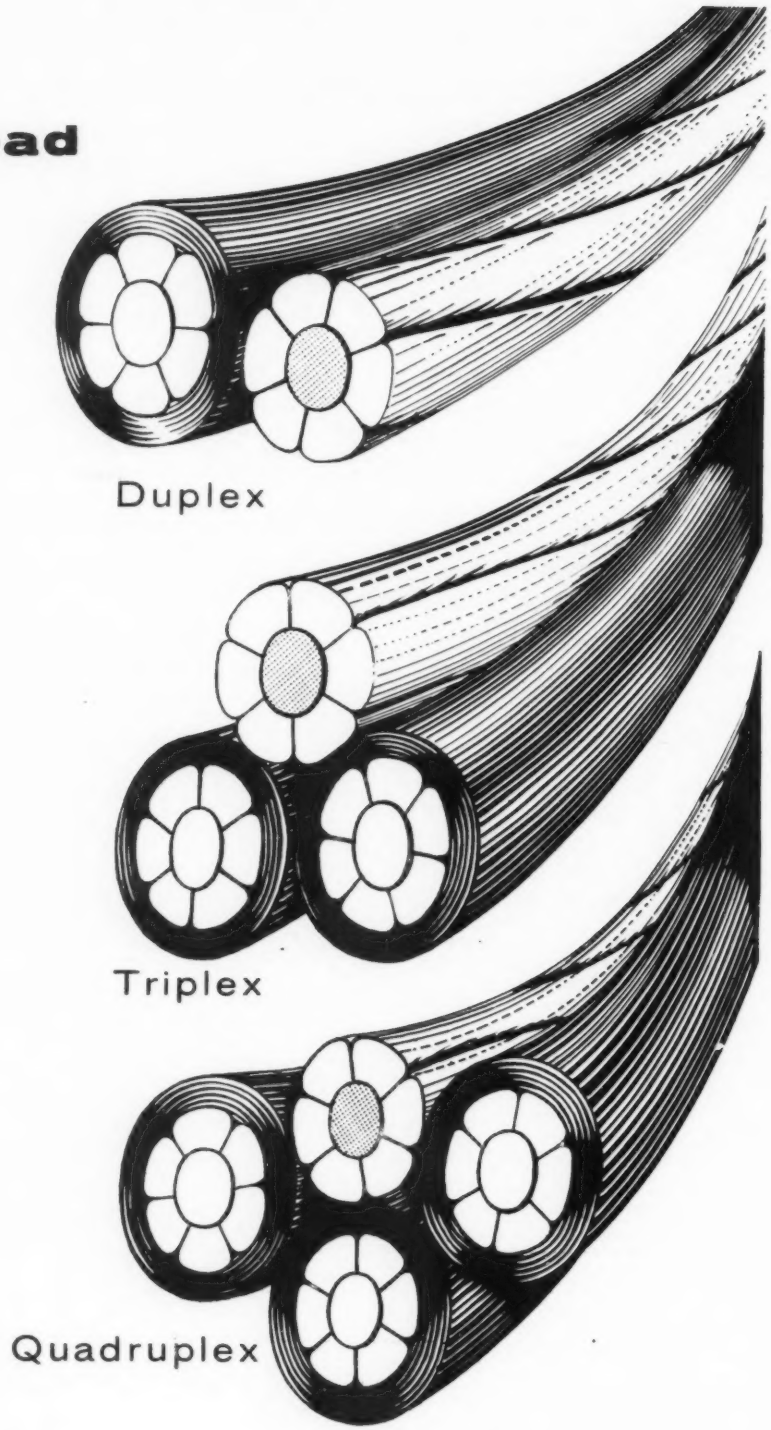
EEC-71

# ALUMINIUM for overhead distribution lines




Self-supporting aluminium aerial cables are the most modern trend in overhead secondary construction. One (DUPLEX), two (TRIPLEX) or three (QUADRUPLEX) polythene insulated aluminium phase conductors are supported by a bare ACSR or aluminium messenger which assumes the entire cable tension and also serves as a neutral conductor.

These revolutionary overhead distributors offer many advantages over other systems. There is only one light-weight cable to string, sag and deadend, and this allows shorter poles to be used and economies achieved in hardware, labour and tree trimming. DUPLEX, TRIPLEX and QUADRUPLEX cables take relatively little space on the pole top and are neat and workmanlike in appearance. They are less subject to interference from trees than open wire and service continuity is ensured even when the poles are down!

Although the messenger is strong enough to carry very long service drops, these are seldom necessary as the cables can be tapped on the span.

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# Establishment of Super-Grids
## Organizationl Procedure for their Control

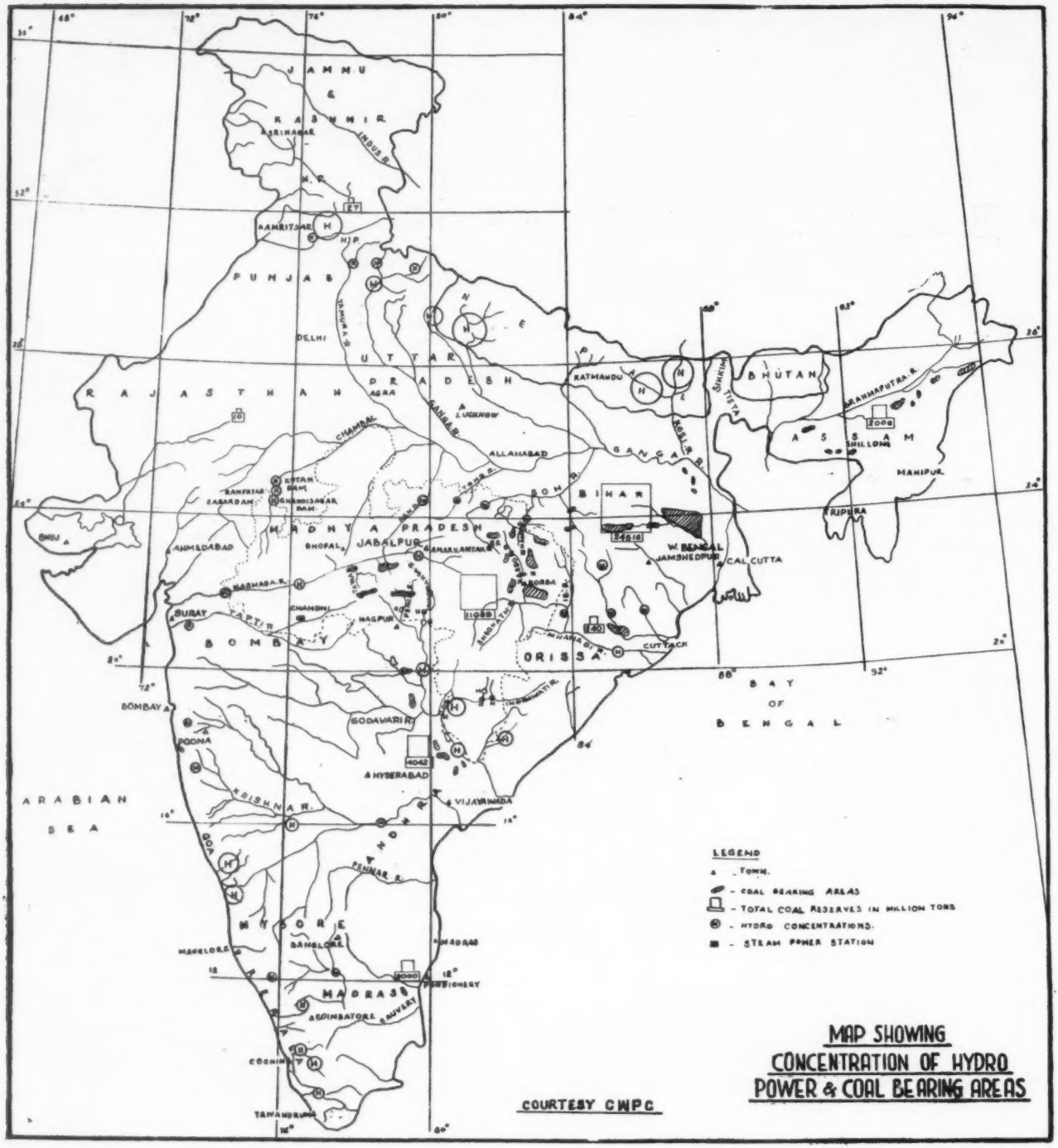
IT WILL BE APPROPRIATE IF A REFERENCE IS MADE to the reasons leading to the inclusion of this subject in the discussion at this Seminar*. Shri Jaisukh Lal Hathi, Union Deputy Minister for Irrigation & Power in his concluding speech at the Sixth Irrigation & Power Seminar at Hyderabad had with reference to the subject "Trend of load growth in various regions in India", observed : "It is gratifying to note that a broader outlook was clearly visible in the discussion and speeches made by several speakers on this question and in reports of Sub-Committee. The recommendation of the Sub-Committee with regard to inter-State exchange of power, which is the result of this expression of opinion during the discussion, is a most welcome one. We have to develop a national outlook. The natural resources of our country are national resources and wherever these natural resources are located, they are meant to be utilised for the country as a whole and not for any particular region or State. This outlook is a happy augury for the future and I am sure the engineers will continue to develop this outlook to a still wider and greater extent. It was rightly suggested that the engineers should not mind as to where the power station is located. What he should care for is that the power is made available in that particular area. It is not the source of power generation that is essential but it is the supply of power to that particular locality. There should be no boundary restrictions for the transmission of power from one area to another. With this end in view it is but proper that the Committee has suggested that the power system planning, which has been confined to the State boundaries so far, has to be extended over the adjoining States for ensuring maximum benefit to the country as a whole. It has also been recommended that inter-State exchange of power will also have to come in a large measure in the future Five Year Plans. I think this is one of the greatest steps which the Power Engineers have taken at the Seminar and the Sub-Committee deserves congratulations for the far-sighted recommendation which they have made in their report."

* This was a paper submitted to the Engineers Seminar held at Bangalore, 1960.

The present subject namely, "Establishment of super-grids and organizational procedure for their control" is, therefore, the direct result of the Sub-Committee's recommendations and the trend of observations made before the Power Engineers at the Hyderabad session.

### Need for Super-Grids

An examination of the Coal Map of India and the developed and potential hydro-electric sources along with the load picture presented by the C.W.P.C. in their report "Forecast of Power Demand in India" indicates that many areas in the country will in future have to depend largely for their power requirements on sources situated at considerable distances away from the load centres. This is the result of the full utilization of the cheaper hydel sources available within the area and the long haulage of coal involved for any new thermal stations to be established within that area. Interconnection of the various existing power sources both hydel and thermal in the neighbouring States is, therefore, a proposition of considerable importance. It will provide for the interchange of power and for achieving improved efficiency and economy, reduction of standby capacity and greater security of supply. If this is agreed in principle, and the Planning Commission seem to accept it, then future thermal power generation will be based largely if not entirely on super thermal stations to be established at the pitsmouth. It also follows that such stations must necessarily utilise the high ash plus moisture content coals only which cannot be used by any other industry and are uneconomical to transport. This concept of power generation by utilising low grade coal at pitsmouth is based on the assumption that such coal will be reasonably priced for its thermal value. If it be priced nearly as high as high grade coal, the entire thesis breaks down. In fact, power generation at pitsmouth based on high ash content coals will then cease to be a practical proposition. It will be essential, therefore, to lay down a correct pricing policy for the low grade coal and evolve a cost formula which bases price of the coal largely on its heat content. Pre-




COURTESY CWPC

**MAP SHOWING CONCENTRATION OF HYDRO POWER & COAL BEARING AREAS**

sumably this matter is already under examination by C.W.P.C.

In so far as the planning for future thermal power generation based on utilization of inferior coal is concerned, it can be said that this will be restricted to a very limited area. If power from this area is to be transmitted in bulk to the neighbouring States and other areas, the question of transmission over long distances and the establishment of super grids for this purpose will naturally arise. This follows from the proposition as already stated that transport of coal, especially of inferior variety, over any distance will be uneconomical and unjustifiable and will also be a heavy burden on the Railway transport system.

### Some Technical Considerations

(i) For transmission of power over long distances the question of voltage at which this has to be done must be considered carefully so that the power development programme of the various States during the Third and Fourth Five Year Plans may be so oriented as to facilitate the establishment of super-grids at this voltage as and when it becomes necessary. The highest voltage in use at present in the country is only 220 kV and this may not be adequate for transmitting larger blocks of power over long distances. Higher voltage, say 380 kV or 400 kV if adopted for the super-grid would facilitate transfer of about 300 MW upto a distance of 600 miles. Some of the E.H.T. lines contemplated for supergrid could possibly be constructed for this voltage if considered necessary and operated at lower voltages, say 220 kV, until the need arises for raising the voltage to the higher level. This would no doubt involve additional capital expenditure, but the likely saving in the long run would be considerable. How and in what proportion the initial additional cost on the 380/400 kV line should be met by the beneficiary States concerned will be one of the problems which could be easily solved.

(ii) Since the establishment of super-grids presupposes the establishment of super thermal stations, there is also need for determining the sizes of the individual units in these power stations and the pressures and temperatures to be employed. A standardization of these keeping in view the capacities of the individual grid systems would be a step in the right direction. It may be economical and advantageous if super thermal stations ordinarily do not go in for sets below 75 M.W. capacity. When the establishment of a super grid throughout the country becomes a reality, sets of larger sizes, say, of 125 mW or 250 mW capacity could be considered for some of the super thermal stations. The thermal efficiency possible with such units would add to the economy of power supplied through super grids.

### Financial and Organizational Aspect

(i) It may not immediately be necessary to enact any special law or to set up any separate organization for the development of a super grid. Under Section 43 of the Electricity (Supply) Act, 1948, the State Electricity Boards can enter into an agreement for the purchase or sale of power with a neighbouring State under certain conditions. Sale and purchase of power between two States is taking place even now to a very limited extent, limited in view of the general tendency on the part of the States to insist on the location of power stations within their territorial bounds irrespective of the economics involved. This ought to be discouraged and in future all large thermal stations should be located at the pitsmouth for utilising the inferior coals so that power may be supplied to the various States from a super-grid system. The aim should be to fulfil the demand for cheap power irrespective of the place from which it comes.

The preliminary procedure for inter-State working may well be similar to that followed by some of the States in setting up multipurpose schemes. A State proposing to set up a large thermal station based on low grade coal may consult the likely beneficiary States about their participation in the scheme and the capital expenditure on the station may be borne by the States in proportion to the benefits shared by them. A joint committee consisting of the representatives of the Electricity Boards concerned could work out the details of the financial arrangements, costs, schedule of operation and transfer of power and other incidental matters. The C.W.P.C. under the present set-up could play an important part in co-ordinating the arrangements between the participating States.

As regards the cost of energy to the beneficiary States, the obvious basis will be the cost of production including the cost of super-grids.

(ii) Under the Electricity (Supply) Act, the Central Electricity Authority is charged with the duty, among other things, of co-ordinating the activities of the planning agencies in relation to the control and utilisation of national power resources. With the guidance of C.E.A. and C.W.P.C. the existing organisational pattern with proper co-ordination between the States should be workable in the initial stages of the development of super-grids. As experience is gained, detailed procedure can be evolved and any new enactment found to be necessary can be brought to the notice of the C.W.P.C. and the Central Government.

(iii) National super-grids may take some time to develop. Meanwhile, it would be advisable to plan power generation in the Third Five Year Plan with the object of establishing inter-State super-grids so that large thermal power stations are put up in areas which have abundant low grade coal and which could be utilised for power generation for supply both to the State of origin and to the neighbouring States. States away from coal resources should not be chary of taking advantage of the resources of

[*Continued on page 26*]

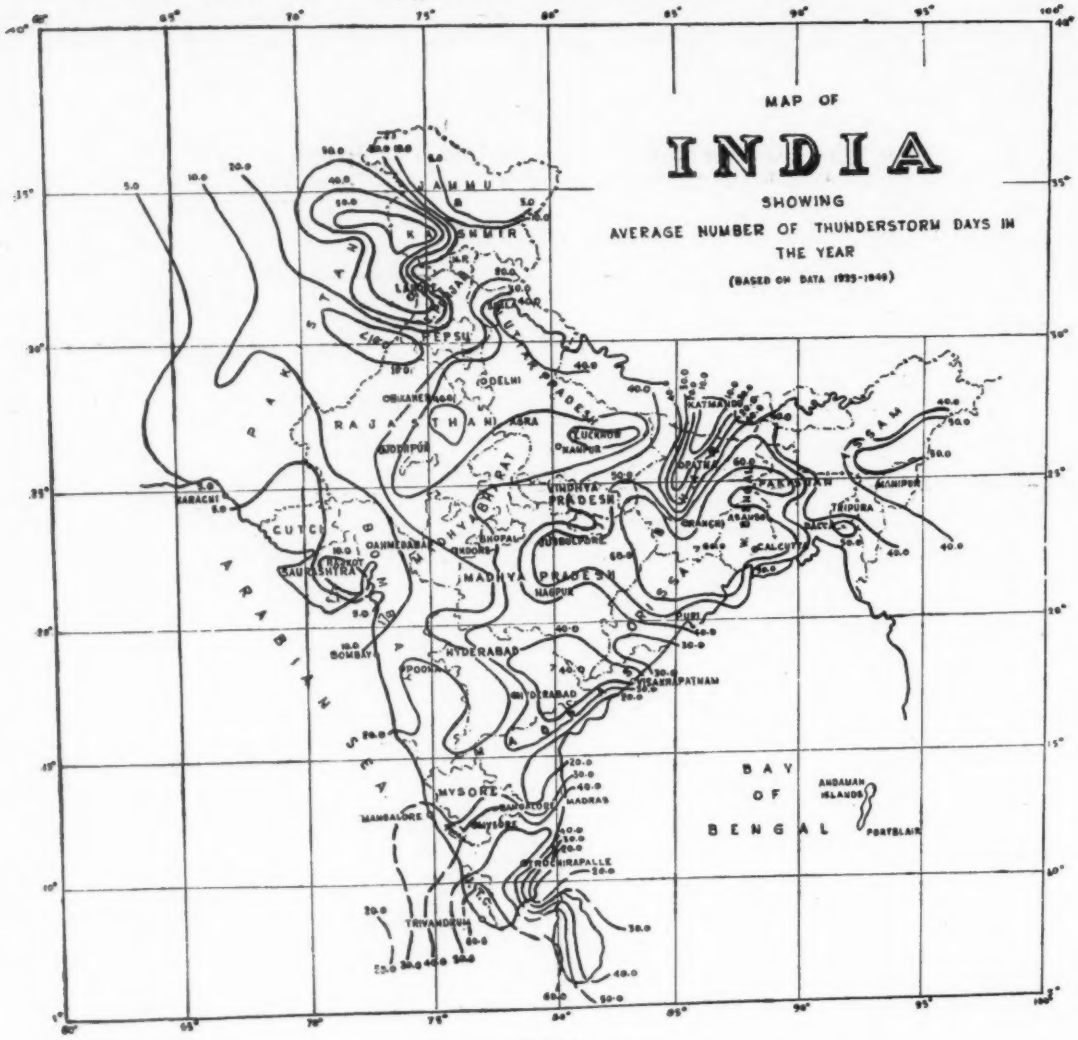



FIG. 14

MVA, steam turbines and generators of 60 MW and above, synchronous condensers up to 1,500 kVA. Negotiation is already afoot for the establishment of two more heavy electrical works in the public sector under the Third Five-Year Plan. There are ample opportunities for British electrical firms who can manufacture in India.

## 10. RESEARCH

The Central Water and Power Commission has been entrusted with the setting up of organisation with laboratories—

(i) to investigate economic utilisation of energy resources
(ii) to effect technical efficiency and economy in the supply industry, and
(iii) to promote the manufacture of equipment with indigenous resources.

## 11. THE FUTURE

When Lenin said that "Electricity plus Soviet is Communism", he stressed the necessity of placing horse-power in the peoples' hands, before a target of industrial production could be achieved.

India similarly cannot thrive unless strong emphasis is given to the role of electrical energy in raising the standards of living of the Indian people. Power supply and distribution must continue to grow and expand.

The major problems of energy production have certainly not all been solved. Those who are engaged in the field of power engineering in India can rest assured that the future holds much to keep them interested.

India today offers to the power engineers almost a virgin soil. The future problems will be great, but enthralling and stimulating.

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# GAS TURBINES SHOW THEIR BREEDING

Brown Boveri gas turbines have the "solid" look of steam turbines. The casings are machined castings. The rotor shafts are large. Bearings and other parts are easily accessible. Each turbine has a single, rugged combustion chamber.

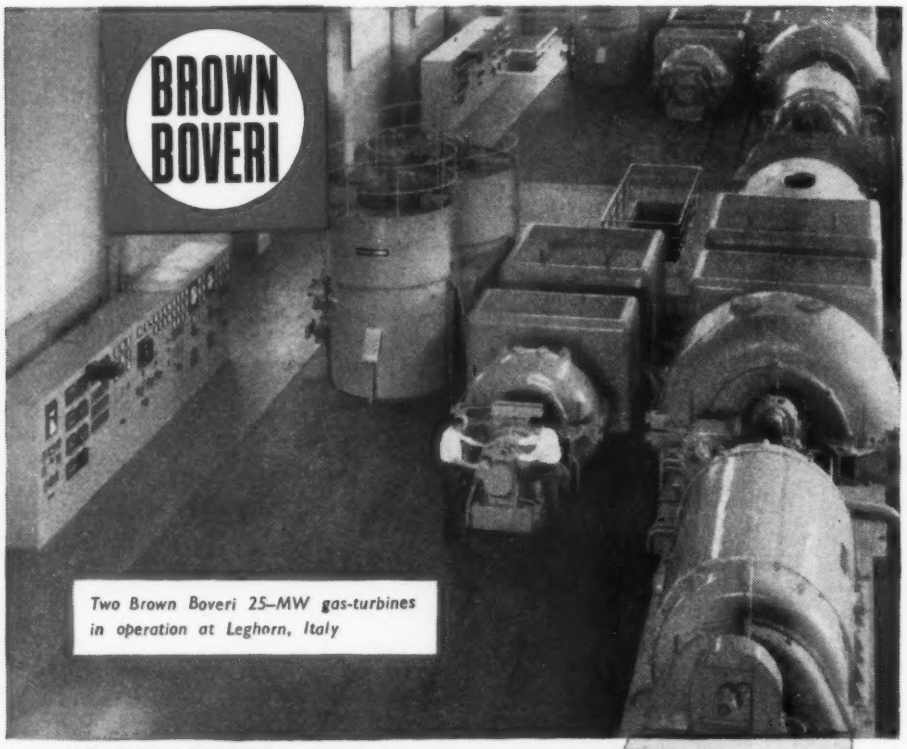
This family resemblance comes naturally. Brown Boveri gas turbines were designed from the start for continuous stationary service... in contrast to lightweight units adapted from aircraft engine designs.

The first large gas turbine-generator, a 4,000 kW unit, was built by Brown Boveri and installed in 1939. It is still operating.

The world's largest gas turbine generating plant at Port Mann, Canada, is unattended! Its four 25MW Brown Boveri units are fully automatic and remote controlled.

Overhaul of two Brown Boveri gas turbine sets at the Pertigalete Cement Works, Venezuela, showed a typical condition: after 15,000 operating hours, components were almost like new. No sign of wear. No repairs or parts changes required.

Scores of Brown Boveri stationary gas turbines totalling over 1,300,000 kW installed capacity are driving generators, compressors and blowers in nearly continuous trouble-free operation—year after year. No other manufacturer can match this experience.




*Two Brown Boveri 25–MW gas-turbines in operation at Leghorn, Italy*

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# Gas Turbine Power Plant in Canada

FOUR LARGE GAS TURBINES WILL GENERATE electricity by driving alternators at a new thermal power plant on Vancouver Island in Canada. The order was placed by the British Columbia Power Commission with the Canadian General Electric Company. It is believed that when this plant is in operation it will be the largest industrial gas turbine installation in the world. Single-shaft gas turbines built at the American General Electricity Co's Schenectady works, New York will be used, but much of the equipment is of Canadian manufacture.

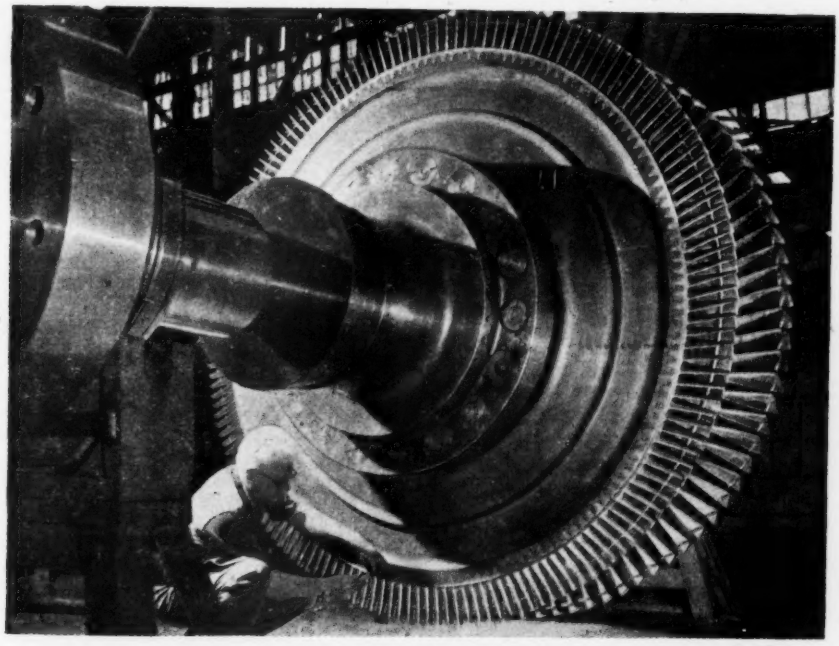
## Power Station Design

There are several notable features applied to layout and equipment, both of which apply to Canadian conditions.

The station will be built on a rocky peninsula of Vancouver Island about 50 miles north of Victoria. The plan for the station is shown in Fig. 1, and it will be seen that the long, narrow layout, with the four units in line, is well adapted to the site. Preliminary studies indicated that this layout should also result in a low building cost. The first two units are of simple-cycle, single-shaft design directly coupled to a hydrogen-cooled generator, 25,600 kva, 0.85 PF at 30-psig hydrogen pressure, 13,800 volts, 3 phase, 60 cycles, while the second two units are regenerative-cycle, single-shaft units, coupled to similar generators by a flexible, quick-disconnect coupling. All four generators can be uncoupled from the gas turbines and run as synchronous condensers when desired, but the special special coupling enables the changeover to be accomplished very quickly on the regenerative units.

The simple-cycle units are rated 19,750 kW at 50°F and 200-feet altitude and the regenerative-cycle units are rated 18,000 kW at 50°F and 200-feet altitude. They are capable of increased capacity at lower ambients.

The selection of two types of gas turbine units was dictated primarily by the type of load predicted for the thermal plant. For the first two or three years of operation, while new hydro stations are being built and their reservoirs filled, the units of



Single-shaft Turbine Rotor at the manufacturing plant.

this thermal plant will operate at high load factor. Under such operating conditions, the increased thermal efficiency and resulting economy or regenerative units make them preferable to the simple-cycle units. Subsequently, when part of the plant may be relegated to standby and peaking service or operated during periods of low-water, the regenerative units would be put into operation first to benefit from their lower fuel consumption. A further factor in the selection of two types of turbine

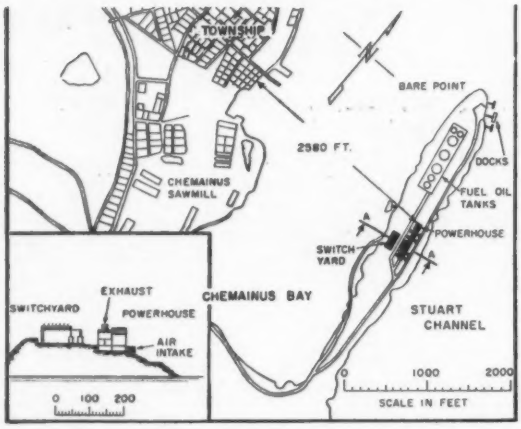



FIG. 1 Site Plan of Georgia Power generating Station.

units relates to delivery of units. The simple-cycle units were already designed and in production, and so could be delivered in a much shorter time than the regenerative units, which required further design before production. The simple-cycle units could, if required, be adapted at some future date to furnish heat for a steam plant by the addition of exhaust-heat recovery boilers, thereby improving the overall thermal efficiency to equal that of the regenerative units. The final selection was, therefore, two simple-cycle and two regenerative-cycle units. All units will burn residual fuel oil, usually called "Bunker C," which will be treated at the site to the turbine manufacturer's specifications to eliminate corrosion problems in the high-temperature parts and to minimize deposits.

A floor plan of the station is shown in Fig. 2. The differences between the simple-cycle and the regenerative units ar readily apparent. However, the general designs of the units are enough alike so that much of the layout and engineering could be duplicated on all four units by the consulting engineers. The straight-forward design of the station and the simplicity of the installation should be noted. While every effort was made to ensure a low-cost installation, nothing was omitted that would help the operation or affect the reliability of the station. (Fig. 2A).

In the description of the units, which follows, the basic simple-cycle machine will be described first, and the changes required to provide the regenerative feature covered later. Also, while the description applies particularly to these units, five other gas turbines of the basic simple-cycle design have been or are being built at present for other power plant installations.

## Simple Cycle Units

These units are single-shaft gas turbines consisting of a 15-stage, axial-flow compressor, solidly coupled to a two-stage, impulse-type turbine, with the turbine solidly coupled to the generator. The turbine-generator unit is designed to run at 3600 rpm. The combustion chambers are built into the turbine mid-frame between the compressor discharge and the turbine inlet. The starting motor, the accessory drive and the oil tank are at the compressor end of the unit. Figure 3 shows the major dimensions and general ppearance of the unit.

The compressor is of conventional construction

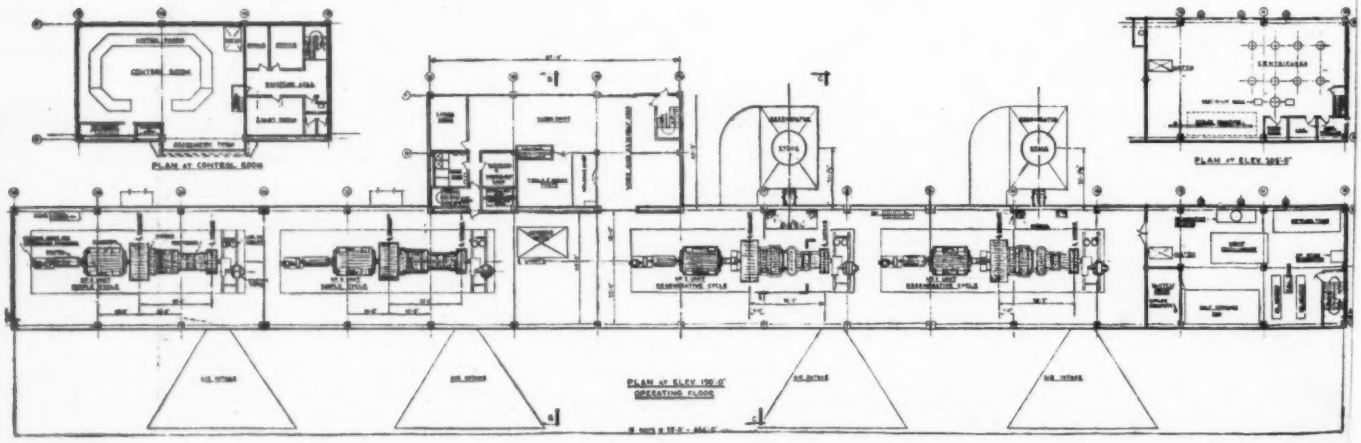


FIG. 2 Layout of Operating Floor of Station

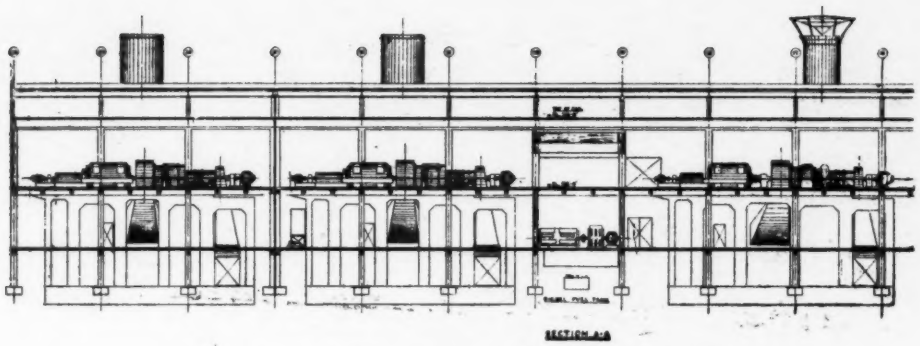


FIG. 2A Part of longitudinal elevation of Power Station

except for its size. The inlet casing is made up of a cast cylindrical section, with a bell mouth, forming the casing for the first four stages with a fabricated hood bolted to it to form the complete casing. The hood can be oriented to put the inlet opening either above or below, as desired by the purchaser.

### Combustion System

The sixteen combustion liners are generally similar to those now used in smaller units. Some modification has resulted from tests and a development program to reduce pressure drop in the combustion system. These large units are designed to burn residual fuels. The fish-tails that make the transition from the circular combustion chamber to the nozzle annulus are of standard design.

### Turbine Design

The turbine comprises two stages of typical wheel and diaphragm construction as used in both our steam and gas turbines. The turbine wheels are machined from separate pancake forgings of a modified 12-per cent chrome, ferritic alloy. In the first units of this type built, they are bolted together and bolted to the compressor end and generator-end stub shafts through integral flanges. (Fig. 4). To reduce the thickness of the forgings, this was changed on the units for British Columbia Power Commission to a through-bolted construction. The

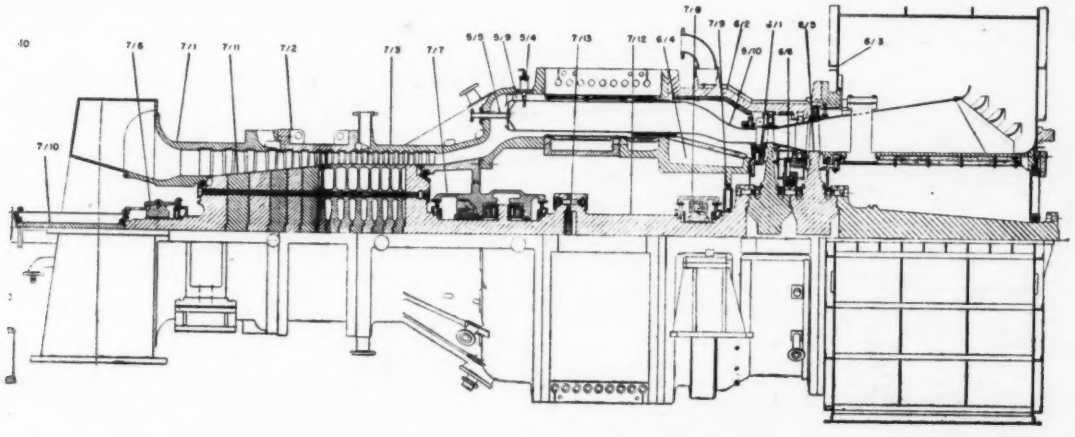


FIG. 3 Longitudinal cross-section of single- cycle single-shaft gas turbine unit.

5-4. Spark plug
5-5. Fuel nozzle
5-9. Combustion chambers
5-10. Transition piece assembly
6-1. First-stage nozzle
6-2. Turbine shell
6-3. Exhaust hood
6-4. Turbine frame and No. 3 bearing
6-5. Turbine rotor assembly
6-6. Second-stage nozzle
7-1. Inlet casing assembly
7-2. Compressor casing assembly
7-3. Discharge casing assembly
7-6. No. 1 bearing assembly
7-7. No. 2 bearing assembly
7-8. No. 3 bearing assembly
7-9. Air seal for No. 3 bearing
7-10. Accessory gear—compressor coupling
7-11. Compressor rotor assembly
7-12. Compressor—turbine distance piece
7-13. Compressor—distance piece coupling

first-stage buckets are made from cobalt base, high-temperature alloy; the second-stage buckets from a 12-percent chrome, ferritic alloy, modified with tungsten, molybdenum and vanadium to improve the high-temperature properties. Both the first-and second-stage buckets are attached to the turbine wheels by axial-entry pinetree dovetails. There are no covers or shrouds attached to the buckets. Close clearances are, however, maintained between the tips of the buckets and th stationary shrouds. The special means adopted to maintain these clearances will be described later.

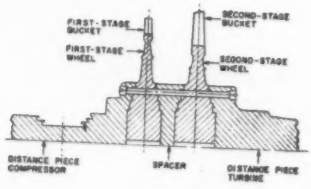



FIG. 4 Details of through-bolted gas turbine wheel.

The first-stage nozzle is air cooled, and since these machines burn residual oils, is equipped with X-40 partitions. The air is bled from the end of the annular combustion chamber space and passes radially inward through the partition into cups on the inner sidewall, where it turns and passes through holes in the inner wall, just upstream from the leading edge of the partition, back into the main gas stream. The second-stage nozzle does not require cooling. (Fig. 5).

Both the first-and second-stage turbine wheels are also air cooled. Air is bled from an appropriate stage in the compressor, cooled in a water-to-air heat exchanger.

The turbine shell presents some interesting problems. It is a primary structural member in the unit's construction and forms part of its backbone.

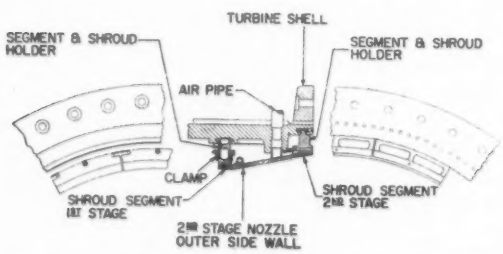



FIG. 5 Details of bucket shrouds and shroud holders.

In addition, it must support and locate the nozzles and diaphragm and the shrouds over a wide range of loads those that occur during transients. The solution adopted is to cool the turbine shell, which is provided with longitudinal ribs or fins and an enclosing jacket, by relatively cool low-pressure air bled from the fourth stage of the compressor. This will keep the shell at a relatively low-temperature and minimize the possible dimensional changes. The first-stage nozzle and second-stage nozzle with its its diaphragm are supported centrally by radial pins or keys with sealing strips that do not restrict movement, but minimize leakage. The shrouds over the buckets are supported by separate segmented rings with a high-resistance heat-flow path so that they may follow the temperature of the gas stream rapidly and compensate for the diametrical changes in the shell with changing temperature. This enables a more constant clearance to be maintained between the shroud and the bucket tip.

The exhaust casing is designed with a liberal flange area and a diffusing passage in the shape of an annular cone at the last-stage annulus. The axial velocity leaving the second-stage bucket is reduced to about one-half its initial velocity in the diffuser. It is then turned radially outward by means of turning vanes in the hood proper. The net result is the recovery of a good percentage of the velocity energy leaving the turbine and an annlus static pressure lower than the static pressure at the exhaust flange.

Previous mention has been made of the main bearings. These are located as follows: The bearings are standard journal bearings with ball seats for initial alignment of the unit. The thrust bearing is of the pivoted shoe type. Bearing seals are of the labyrinth type, and a vapor extractor is installed the oil tank to insure a constant slight air flow into the bearing housings to prevent oil or oil vapor from leaking out.

## Regenerative-Cycle Units

The design of the regenerative units is based directly on the simple-cycle design. In fact many of the major components, such as inlet casing, compressor casing, compressor rotor, compressor blades, turbine wheels, second-stage turbine nozzle and diaphragm, and turbine exhaust hood are interchangeable between the two designs.

The changes made involved only the compressor discharge casing, the turbine shell, and the combustion area, which is now external to the machine. It was originally hoped to make the necessary changes and still maintain the same over-all length of the unit; but it finally proved necessary to increase the length.

The combustion system is entirely different. The 42-inch line from the compressor discharge goes directly to the regenerator air inlet. The preheated air discharged from the regenerator goes directly by two (2) 30-inch diameter lines to the inlets of the two combustion chamber pods, as shown. The discharge from the combustion pods is downward through the 42-inch lines, which turn upward in a U-bend and connect to the "pants leg" in the lower

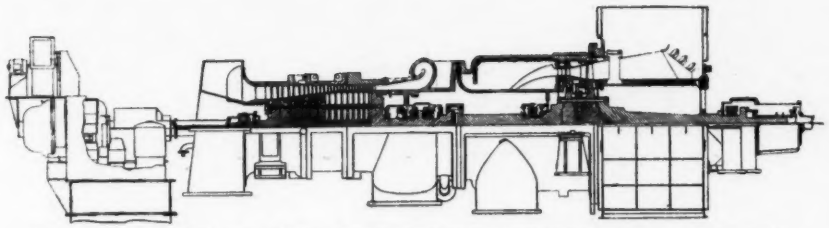


FIG. 6 Longitudinal cross section of Regenerative-cycle, single-shaft gas turbine units.

NOTES

1. For torquing value of bolts not specified, use K-9187408 or 974A780 where applicable.
2. At assembly apply lubricant per 118A449.
3. At assembly apply anti-seize as per K-9692691 PT-1.
4. Wet bearings and journals with an SAE 30 or heavier oil before placing the journal into the bearing.
5. Wet ball surfaces of journal bearings with D6B1C oil immediately before installation of shaft in the bearing.
6. Splines, hubs, coupling rabbet and shims to be match marked at assembly.

half of the turbine shell. These U-bends contain the expansion joints that allow for the relative movement between the turbine and the combustion pods and regenerator.

## Accessories and Control

The accessories and control for all units are identical, except for a change in the flow divider to supply fuel to sixteen (16) combustion chambers in the case of the simple-cycle units and eight (8) in the case of the regenerative-cycle units.

The fuel and control system for these units is shown diagrammatically in Fig. 7. The fuel system consists of a fuel pump and a hydraulic pump driven through a spline connection from the turbine through the accessory gear as shown on the right side of the diagram. The hydraulic pump furnishes hydraulic power to a hydraulic motor which drives the gear flow-divide system, which proportions the fuel equally to each fuel nozzle and combustion chamber. The gear flow-divider system consists of a series of gear pumps, all mounted on a common shaft, and driven at the same speed by the hydraulic motor. Each gear pump is the same size and passes a flow proportional to its speed.Therefore, each group pump serves as a metering device to supply the correct amount of fuel to one fuel nozzle in its corresponding combustion chamber.

The control system is basically a speed-governing system consisting of a rotating pilot, centrifugal fly-ball governor, and primary relay. The control of the primary relay, through its connecting linkage, positions the pilot valve of the hydraulic pump and thus controls its output, which in turn controls the speed of the hydraulic motor and its connected flow dividers and, correspondingly, the quantity of fuel delivered to the turbine. The output of the hydraulic pump is controlled by stroking the pistons, and this stroking mechanism is, in turn linked to the by-pass valve around the main fuel pump.

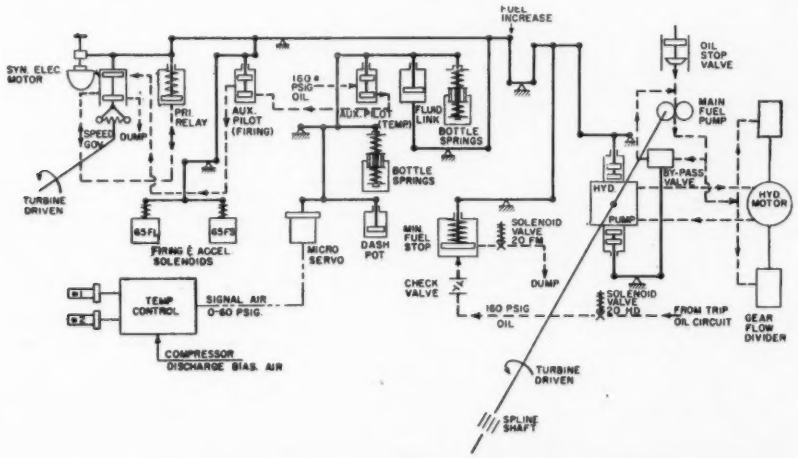



FIG. 7 Schematic Diagram of Fuel system and automatic control.

This then controls the quantity of fuel delivered to the flow dividers to maintain a minimum pressure difference across the gear elements in the flow divider. This prevents minor differences in clearances in the flow-divider elements from affecting the proportion of fuel delivered to the individual nozzles. The oil stop valve shown in the diagram shuts off all fuel to the unit on emergency overspeed.

The lubrication system follows usual gas turbine practices. These units will be provided with a shaft-driven centrifugal oil pump mounted in the accessory gear box to supply oil at 160 psig to the bearing and control oil header. They also have a 75-hp, a-c, motor-driven auxiliary oil pump and a 71″ 3-hp. d-c. motor-driven emergency oil pump on the system under pressure control. Wherever possible, all lube oil piping is double piped, with the pressure feed lines inside the drain lines. The generator, beng hydrogen cooled, has its own seal-oil detraining system and standby pump with oil reservoir for maintaining the hydrogen seal when the unit is shut down.

A bot-type emergency overspeed governor is provided in the inlet-end stub shaft of the compressor which shuts off all fuel to the unit on overspeed by dumping oil from the control system and allowing the oil stop valve to close and returning the hydraulic pump to zero stroke. This only operates if the unit exceeds ten-percent overspeed due to malfunctioning in the control system.

A gas turbine is not self-starting and some means must be provided to roll the unit to establish the air flow before ruel is introduced. The starting unit must then accelerate the gas turbine to self-sustaining speed, which is about 50 percent of full speed. A 550-hp. 1800-rph woundrotor induction motor with a solenoid-operated paw clutch is provided for starting purposes. The contractors for the resistors for the necessary speed and acceleration steps are under the control of a selector switch and appropriate relays. The switch has positions OFF, TURNING GEAR, CRANK, FIRE, RUN.

The units are mounted on four rigid supports on the reinforced concrete foundations, about 20 feet above basement grade. The two supports just aft of the turbine bulkhead are the fixed points. Two sliding supports are on the compressor casing These are shown on the outlines, Fig. 3. The generator and exciter and the oil tank will be supported directly on the foundation. The 20-foot height is required to provide room for the inlet and exhaust duct work under the unit, as inlet and exhaust are from below. Space is also provided for the hydrogen seal-oil control unit, the oil tank the generator lead connections, etc.

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ESTABLISHMENT OF SUPER-GRIDS AND .....

[*Continued from page 19*]

a neighbouring State which could generate and supply power economically. The correct policy will be for the States concerned to co-operate for setting up large thermal stations in the low grade coal areas, keeping in view the fact that the natural resources of our country are national resources, wherever they may exist and that they are meant to be utilised for the Country as a whole and not for any particular region or State considering the overall national economy.

C. P. Bhimaya
*Central Arid Zone Research Institute*
*Jodhpur*

# Role of Checkdams in Afforestation Areas

IT IS ALMOST AN ACKNOWLEDGED BELIEF THAT IN all gullied lands resort must be made to check dams. On the other hand in countries like U.S.A. where all their works are mechanised and manual labour is very costly they feel building of check-dams as a waste of money. This paper discusses the merits of checkdams in this country so far as their role in afforestation areas is concerned. The paper deals with the practical experience of the author when dealing with the afforestation of the heavily gullied areas in the Damodar Catchment while working with the Damodar Valley Corporation during 1953-55. The cost figures, materials used and the designs given are with reference to this background.

## Checkdams

Any structure built with any available material across a gully or water channel with a view to break the velocity of water and to cause impounding of water temporarily or permanently together with the deposition of the soil transported by the flowing water is called a checkdam. Thus the size of a checkdams depends on the size of the gully or channel across which it is to be built.

## Types of Checkdams

Irrespective of the material used for building the checkdams they can be built as impervious dams, pervious dams or semi-pervious dams. In the case of the first type it is to be normally built with stone and brick mortar or when it is of a purely temporary nature with earth. Temporary dams can also be constructed of dry stone masonry and clayey soil put in front of the dam upto spillway level. Such a sealing layer is properly tamped and compacted, the structure serves its function properly. In such types of dams it is always necessary to have a spill-way in the middle of the dam.

Pervious dams could be built with dry stone masonry, keeping the interspaces unsealed. These could be built with any other material that are normally used in checkdams without sealing the crevices.

Semi-pervious checkdams can be built of the same material as the pervious checkdams but in their case a screening layer of pebbles or gravel should be put up against the upstream side of the dam. In this case also it is better to provide a sort of spillway in the middle of the dam.

## Functions of Checkdams

Checkdams are resorted to in afforestation areas only to help stabilisation of the gully bottoms and to afford a stable planting site inside these gullies Normally impermeable or semi-permeable dams should not be used in such areas. The impermeable dams and for that matter the semi-permeable dams also impound water and hold it on for a long time. In the case of the latter, after one or two showers when silt loads are carried down and impounded by these dams, the silt and the other debris start sealing up the interspaces in the structure and the dam ultimately becomes impermeable and will impound water almost as thoroughly as the impermeable dam. Such an impounding process may contribute a little to the soil moisture in the gullys and to humidity but will make the gully and stream beds unfit for planning. Stagnant water will kill the seedlings of practically all species.

Thus in afforestation areas only pervious dams have to be resorted to. These pervious dams should not be built with large crevices as they do not arrest the flow of water effectively and so no soil deposition takes place. Even such pervious dams tend to become semi-pervious and if allowed to continue as such become impervious in due course. Such a process takes place at a very fast rate where lot of dead leaves and other vegetational material is carried by the flowing water. For this purpose a periodical cleaning to remove all such accumulation on the upstream face of the dam is necessary. With a properly functioning semi-previous dam, however, lot of soil deposition takes place in front of the dam in the gully or stream bed. If the impounding of water does not last for more than a day or two by such semi-previous dams species like *Eucalyptus* and bamboos may be successfully planted on gully bed where soil moisture regime is very much beneficial.

Thus the role of checkdams in afforestation areas is, therefore, limited and they should be resorted only if the cost is reasonable. However, in afforestation areas which are in the immediate vicinity of river valley projects where the silt load carried from such areas is likely to affect the capacity of the

reservoir spending an extra sum on these checkdams is justified. Actually in such afforestation areas the function of the checkdams is required only for a couple of years because by then the entire area gets covered by grasses and shrubs. Only temporary checkdams are, therefore, necessary. Cost of such structures works out to be about Rs. 15/- per acre.

### Materials to be used for Checkdams

Anything like earth, gunny bags filled with sand, brush-wood, wooden poles and random rubble can be used for this purpose. However when the size of the dam exceeds six feet and considerable flow of water is expected it is desirable to use large size stones. Otherwise stones of about 10″ to 15″ length and 6″ to 12″ width serve the purpose adequately.

(a) Earthen checkdams can be used in small gullys or wider gullys with shallow bottom. But in all cases unless the flow is limited and no over-flowing is expected they should be resorted to only if there are means to provide a spillway in a place other than over the dam itself. If there is the likelihood of even a small flow over the dam it will be completely breached. The spillway should be provided along side the dam over a spot which is lower than the dam and through which water can flow down without causing any erosion, such as an exposed rock or good cover of grasses etc. Such dams are the cheapest and most efficient. If the region gets torrential rains it may also be necessary to pitch the dam with stones which could be anything from small random rubble to pebbles. Otherwise turfing could be done. Such dams easily last more than two seasons.

(b) Gunny bag checkdams should be used only in small gullys, particularly if the bags are easily available and are cheap. These dams are not likely to last more than one season.

(c) Checkdams with brushwood alone cannot be constructed. Some stiffening material such as wooden pegs or posts are required for anchorage. With posts and poles made to form a frame, considerable sized checkdams can be built with brushwood. Such a brushwood dam about 5 feet long can be built for less than Rs. 2/- each where material is readily available near the site.

(d) Wooden poles can be used in a close knit pallisade and with proper support in front and behind, especially behind, dams upto 10′ long could be constructed to function quite efficiently. In such structures sheets obtained from old kerosene tins can be nailed inside to make the structure semi-permeable and by puncturing some holes in the tin sheets at suitable intervals, the same structure can also be made permeable. If the material used is coated with coaltar the structure easily lasts 4 to 5 years. Such a dam of about 10′ length costs less than Rs. 20/-.

(e) Lastly with stones, also collected locally, quite efficient checkdams can be constructed by dry stone packing. A 6′ long checkdam will not cost more than Rs. 2.50 if the material is readily available near the site.

All the above charges are indicated on the basis of a daily wage of Rs. 1.50 and assuming that the labourers are trained for the purpose.

### Layout of the Checkdams

Normally there is no need for a regular contour survey of an afforestation area for layout of checkdams. Checkdams should be located at the narrowest necks in the gully beds where the structure will cause the maximum impediment and impounding of water, either temporarily or permanently depending on the type of checdam. A sectional survey of the gully bed may also not be necessary because it may not be possible to locate the checkdams at every suitable point. Usually the location is adjusted to suit the maximum impounding of water. Selection of sites by an experienced person is, therefore, necessary.

Having selected the sites, the construction of checkdams should commence from the gully head downward.

### Designs and construction of checkdams

(*a*) *Earthern checkdams* :

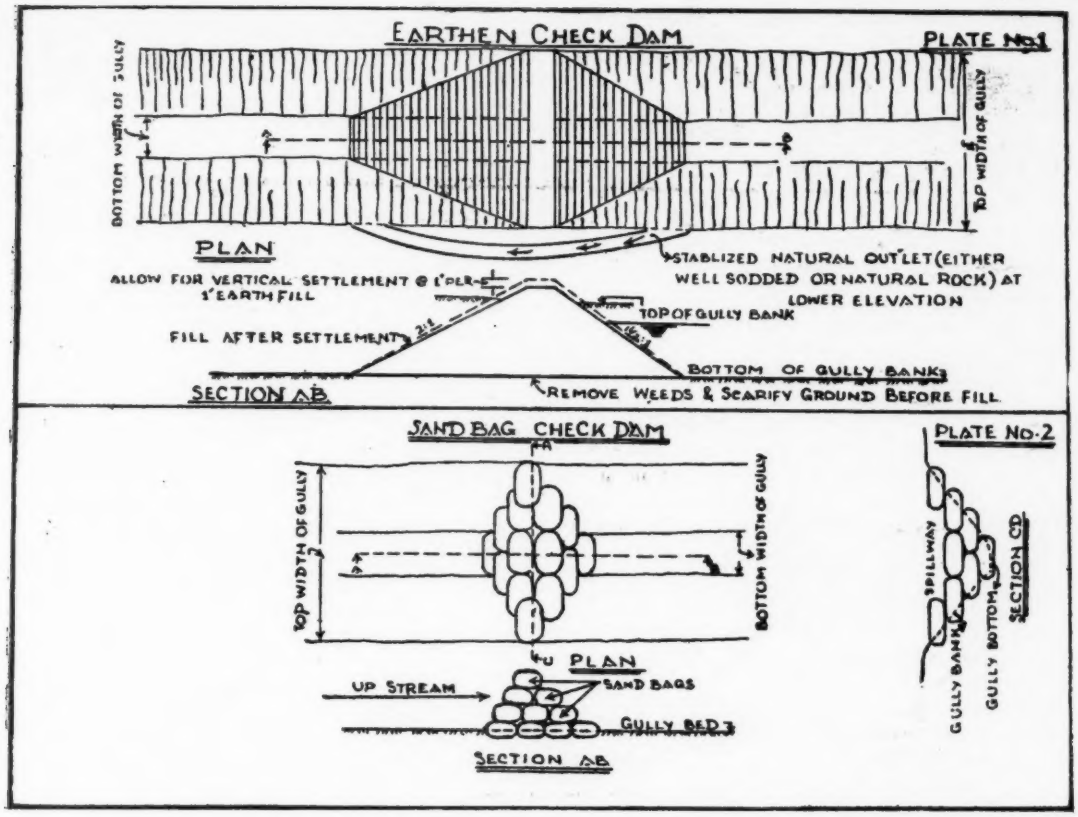
Normally for these structures there is no need to dig a foundation. However, it is quite necessary to have a grass and shrub free bed in which the soil is put and the dam formed. For this purpose it is necessary to scrape the gully bottom and the sides and make them even and vegetation-free. The soil should be put in layers of a few inches at a time and properly consolidated by ramming. The sides are to be given a slope of minimum about 1 in 1 and the top be rounded off to prevent the dam being used as a path across the gully. Turfing or stone pitching may be done where necessary. Sketches showing the designs are given in plate I.

(*b*) *Sand bag checkdams* :

For these structures normally no foundation and side bedding are dug. However, digging of foundation is advantageous. The best design for these is to have a structure with a steeper slope inside and have a very gentle slope on the outer side so that there is stability and the water that spills over, flows down smoothly outside. The sketches in plate II illustrate this.

(*c*) *Brushwood checkdam* :

These checkdams require vertical pegs for an-

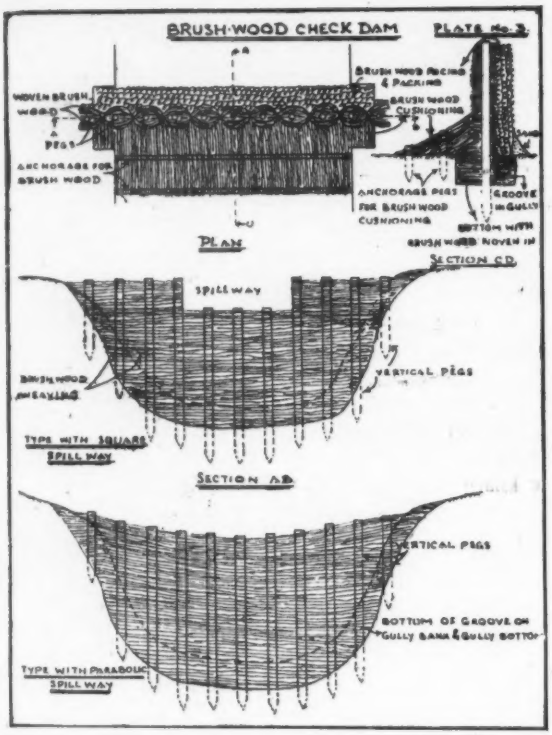



chorage of the brushwood. In order to prevent effectively water from running around the ends it is better to cut grooves on the sides of the gully and also cut a similar groove at the bottom of the gully to prevent side and underscouring. The width and depth of such grooves depend on the size of the checkdam and corresponding size of the material used. It is better to prepare the brushwood material ending in a concave top but sometimes this may be more difficult than having a cut spillway in the centre. The wooden pegs which form the vertical support for the dam are driven into the ground firmly to correspond to the concave top or cut spillway having at least a peg each inside the grooves cut at the ends. Fresh pegs cut from species like *Boswellia serrata* or *Lannea grandis* can be used for the purpose so that they may strike roots and form live pegs giving a longer life to the dam. The brushwood material is properly woven round these pegs either very closely packed and a facing layer of brush wood given on the upstream side, if a semi-permeable dam is required, or loosely packed if it is to be permeable. However, in the case of a permeable dam of this material it may become semi-permeable dam after a couple of rains due to the leaves etc. packing up the crevices in between and soil sealing up the interspaces. When weaving up the brushwood care is necessary so that the material is properly packed into the bottom groove as well as in the side grooves and also that the central spillway is properly formed. After the material is woven up and the bottom and sides are properly sealed, care is also necessary to make a brushwood cushion on the downstream side of the dam. Otherwise the spilling water scours the bottom of the gully and dislodges the pegs and the dam completely. Sketches in plate III illustrate the design and other detals.

In the case of the sand bag and brushwood checkdams it may be advantageous to plant on the upstream side either aloes, bamboos or *Vitex negundu* cuttings so that when they are established, they may themselves serve as a checkdam. Such plantings, however, could be done only if the dam is either permeable or semipermeable.

(*d*) *Pallisade checkdam* :

For these structures proper-sized wooden poles or *ballies* are needed. It is better to use dried material which lasts longer. The durability can be further enhanced by coating these poles with coal-tar, creosote or soaking in "*Ascu*". While constructing these pallisade checkdams it is advisable to make grooves both on the sides as well as at the bottom of the gully bed. In this case the groove should be just about the diameter of the poles used for the




purpose. These poles are then either driven into the ground with a mallet, if the ground is soft or are fixed in grooves or holes which should be deep enough to afford stability. While fixing them thus the central posts should be kept a foot or more below those on the sides to provide a spillway and the width of this spillway could be regulated according to the estimated flow. After making the pallisade and fixing the poles firmly by wedging in stones etc. into the groves the top ends of the poles could be sealed by nailing down a half sawn pole over the top using a nail. This will properly reinforce the dam. If the dam is rather too long or high then a half sawn pole could be nailed to the dam on the down stream side and struts, properly nailed and anchored in the ground. Then, if it is felt that a semi-permeable dam is required, old kerosene tin sheets or tar drum sheets properly perforated can be nailed on to the dam on the upstream side. In order that there is no scouring due to the water falling from the spillway it is better to put some stones etc. on the downstream side and anchor them in position by having cross beam or pole anchored in position in its turn with wooden pegs.

The sketches in plate IV illustrate the design.

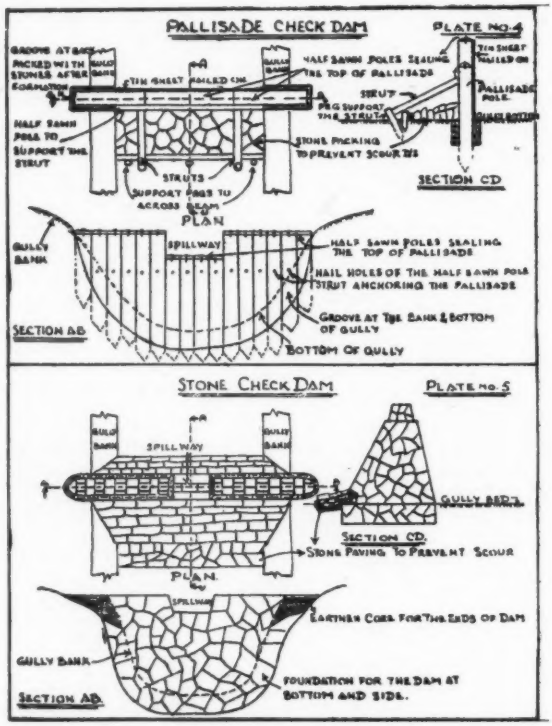
(*e*) *Stone checkdams* :

As already mentioned, these checkdams are built with random rubble collected at the spot. If square-faced stones are available it is possible to build large-sized permeable and semi-permeable checkdams. In the event of odd-shaped stones available only small-sized checkdams should be constructed.

For stone checkdams it is necessary to dig a foundation up to a foot in depth in the gully bed. It is also necessary to make grooves on the gully banks to give a firm anchorage.

Larger-size stones should be placed in the foundation to give better stability to the structure. The batter in the upstream side could be very much steeper but on the down stream side it should be very gentle. Actually on the downstream side the construction should be such that there is a sort of concave channel-like arrangement so that the water discharged by the spillway concentrate along the centre of the structure and thereby prevent scouring the sides of the gully. These checkdams whether permeable or semi-permeable must be built with a central spillway. In order that the water spilling through this spillway and flowing down the dam does not scour the gully bottom some arrangement should also be made to break the velocity of flow after spilling. This could be done by having a row of large stones kept at the toe of the dam.

Sometimes it is likely that due to rather flattish banks it may be necessary to have the dam structure extended on the banks. In such cases it is not necessary to have stone structure right through. On the banks proper earth core walls in continuation of the dams could be constructed and these pitched over




[*Continued on page 32*]

# Season of Floods

THE season for floods has arrived and we have had visitations in Kerala, Madras, Maharashtra and Orissa already. Mr. Bijoyananda Patnaik, the young Chief Minister of Orissa, has set a good example of how to meet the challenge by arranging to announce in advance to the people in the remotest villages about the chances of flooding and by organising relief on an extensive scale by air dropping of food and medicine packets, putting amphibious boats into operation, etc. A permanent organisation for this kind of relief work is being set up and the forecasting and warning stations in catchment areas are being strengthened. This indicates the attitude that in spite of the dams floods to a certain extent are unavoidable and have to be met in this fashion. We agree that this is the correct approach.

However, it is our conviction that Mr. Patnaik was wrong to take the decision regarding the control of waters in the Hirakud Reservoir, which is essentially the task of technical men on the spot. It is true that both the layman and the expert are liable to make errors of judgment. Even so it is better to have greater trust on technical men than on a layman. Mr. Patnaik was, however, lucky this time and we hope that other chief ministers will not take this as a precedent.

* * * *

An enquiry into the collapse of the Panshet Dam near Poona is now being conducted. It is surmised that the collapse may be due to "poor or hasty workmanship". We hope that this was not the case. But if it turns out to be so it will be an advance warning to all of us who are keen to have more and more dams. It has been seen in other countries that in order to control floods of a river system one major dam is never adequate. A succession of dams becomes necessary. But for a poor country like ours this can only be a long term programme. Which means that each dam constructed must be assured of high quality workmanship.

* * * *

The report of the Programme Evaluation Organisation of the Planning Commission dealing with the study of problems of minor irrigation has just been published. It shows from the results of a sample survey that about 54% of the irrigation potential of minor irrigation works remained unutilised in the kharif crop of 1959-60 as compared with 31% in the rabi. This is a considerable degree of underutilisation. Similarly 65% of the sample tanks remained unutilised. On the other hand, the report points out the growth of private tubewells and pump sets which in some cases are tending to lead to over-capitalisation and surplus capacity on the farms. Then again, there were cases of complaints of inadequacy of water due to inadequate and irregular maintenance of the irrigation works, thus affecting paddy and wheat crops or the introduction of new crops.

All these indicate that the situation with regard to minor irrigation works is far from satisfactory. It is of utmost importance that the State Governments gave adequate attention to these problems, for minor irrigation schemes are considered most productive with the least amount of capital investment.

* * * *

We are glad to note that under the Third Plan as much as 13.40 million kW power is expected to be generated. This is 123% of the Second Plan. Initially it was understood that the total generating capacity in the Third Plan would be something less than 12 million kW. This upward revision is indicative of the fact that the Planning Commission has taken serious note of the shortage of power all over the country in recent months. The Third Plan is thus a great advance from the Second and let us hope that its performance will keep pace with its targets, although we believe that even if the full target is achieved the country will still be running short of power.

[*Continued from page 30*]

with stone. By this method besides reducing the cost of construction it is possible to use small stones for the structure which would not be possible if the structure is to be of stone only. When the earthen core wall is made it is necessary to shape it properly and also to consolidate it well before pitching over with stones.

If the stones are large and have uneven faces there may remain large crevices in the course of construction inspite of them being packed with spells and pebbles. In order to make the dam efficient or even semi-permeable it may be necessary to have a screening layer of gravel in the upstream side of the dam.

The sketches in plate V illustrate the design.

The illustrations in all cases are not to scale but only give the general shape etc. of the checkdams.

**Conclusion**

While assessing the need of anti-erosion works it has been found that if the area is badly cut up, checkdams help to conserve soil and moisture. Further such checkdams have greater need in afforestation areas which lies in the catchments of irrigation and hydro-electric reservoirs as they reduce the silt load into such reservoirs and function till the area gets a proper cover of grasses and shrubs that will prevent erosion. Costly checkdams are not at all needed. In order to keep the cost low, material available locally should be used. These checkdams need little or no maintenance and if properly laid out and constructed they serve efficiently till the vegetation takes charge of the site. Only in the case of permeable and semipermeable dams periodical inspections are needed to keep them functioning as silt and dead twigs and leaves are likely to seal them up.

The author acknowledges the help given by Shri C. Gopinath and Shri N. S. Vangani in preparing the fair drawings of the sketches exhibited in the five plates.

## Our Contributors

**Dr. Manoranjan Datta** is Chief Engineer, West Bengal State Electricity Board and has been one of our eminent contributors and as such hardly needs any introduction.

**Mr. K. R. Minocha** passed B.Sc. (Elec. Eng.) from the Banaras Engineering College in 1926 and M.Sc. (Electrical Engineerinfi) from the Masachussets Institute of Technology, U.S.A. in 1928. He was Electrical Engineer with International General Electric Company and Connecticut Valley Power Exchange in U.S.A. from 1928 to 1930. Then Electrical Engineer with Tata Hydro Companies, Bombay from 1930 to 1940; Electrical Adviser to Government, Madhya Pradesh from 1940 to 1945; Superintending Engineer (Electricity), M. P. Government Grid from 1945 to 1952; On Deputation to British Electricity Authority in United Kingdom from 1952 to 1953. He was Chief Engineer, M. P Electricity Board from 1953 to 1957. At present Technical Member, M.P. Electricity Board from 1957. He was Chairman, Institution of Engineers (India), Madhya Pradesh Centre 1950-51 and 1959-60.

**Mr. C. P. Bhimaya.** After receiving the Degree of Bachelor of Arts of the University of Madras in 1931 he underwent train- in Madras Forest College, Coimbatore and entered Madras Forest Department in November, 1932. Rose to be Conservator of Forests in that Department. Worked on deputation with the Government of India from 1942-1946 in the Timber Directorate at Bombay in the supply Department. From 1947 to 1948 in United States of America undergoing training in Soil Conservation, and on return continued to work with the Madras Forest Department as Soil Conservation Officer till 1953. Worked as Forest Officer, Damodar Valley Corporation during 1953 and 1954, and then in 1955 was placed in charge of the Soil Conservation Research Demonstration and Training Centre of the Central Soil Conservation Board at Ootacamund. Was later transferred as Chief Research Officer, Desert Afforestation and Soil Conservation Station at Jodhpur in 1957. On its conversion to Central Arid Zone Research Institute he was appointed as Head of Division in charge in October, 1961. On the appointment of a Director in June, 1960 continued working as Head of the Division of Resource Utilization Studies in this Institute.

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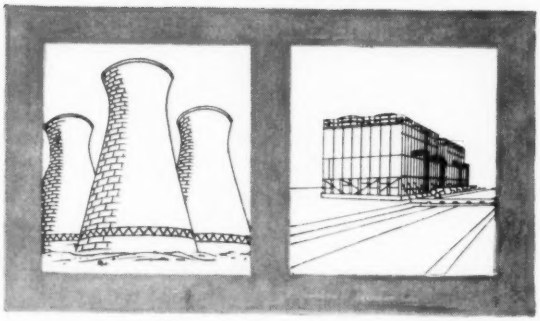

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